

AUTOMOTIVE ELECTRICITY



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AUTOMOTIVE ELECTRICITY

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By

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PREFACE

NO PART of automotive work causes so many hidden troubles as does electrical maintenance and repair. Most of these troubles are extremely simple and easily detected and remedied by one who has an understanding of the nature of electricity and its applications. This knowledge is essential in the diagnosis of troubles and in the intelligent use of the electrical system.

This book has been planned in an attempt to give in as simple and clear a manner as possible the fundamentals involved in automotive electrical systems, and at the same time give a sufficient number of examples of practical applications of these fundamentals so that the reader may get an insight into all possible applications.

The subject treated is such that the book may well be used in grades or in high school classes for the purpose of giving students a fundamental training in electricity or sufficient insight into the subject to familiarize them with electrical repair work as an occupation; it may be used in giving electrical work in connection with vocational auto-mechanics courses; or it may be used by the individual student in gaining useful knowledge which will make readily understandable and applicable the information contained in more advanced books, automobile manuals, and the like.

The author is indebted to many of the automobile concerns for use of material contained in their man-

uials, authors of books on automotive electricity, to the Willard Storage Battery Co., and especially the Electric Storage Battery Co. of Philadelphia, for the reproduction of their charts showing the parts and assembly of the storage battery, electros, etc.

He wishes to express appreciation to C. M. Hewitt, head of the automobile department of Bradley Institute, who checked over the original manuscript and offered suggestions.

GEO. A. WILLOUGHBY.

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CHAPTER I

FUNDAMENTAL PRINCIPLES

1. Electricity.—Just what electricity is, no one has been able to explain, but many of the laws under which it acts are comparatively simple and may be readily applied in making use of electrical power in many

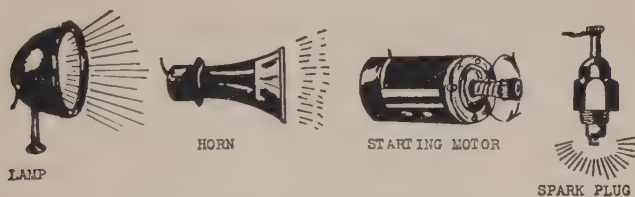
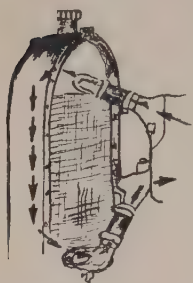


FIG. 1. Common applications of electricity in the automobile.

ways. An understanding of these simple laws places one in a position not only to do certain things but to do them intelligently. Such knowledge assists one also in detecting simple causes of trouble in electrical systems which appear difficult to those not familiar with these important principles. It is the purpose in the following discussions to explain how to do many things and, at the same time, to point out how the fundamental principles of electricity are involved.

2. Electrical Currents.—Before proceeding with a discussion of principles let us consider some of the applications of electricity in the automobile. In Fig. 1 some of these applications are represented. Electrical power is used for lighting the head lights, the dash light, and various other sources of illumination; for operating the horn or other signal; for operating the

starting motor which eliminates the necessity of cranking the engine by hand; for furnishing the spark in the cylinders for the ignition of the gas; and for various other things with which the reader may be familiar. All of these results are obtained by the use of electrical currents but before we consider these, which are more or less mysterious in that they cannot be seen, let us consider some other points which are readily visible and understandable.



WATER CURRENT



PUMP

FIG. 2. The cooling-water circuit and source of pressure.

In water-cooled automobiles the circulation of water thru the outer shell of the motor is a comparatively simple process, as is also the circulation of oil for the purpose of lubrication. These two processes are not unlike those brought about in the electrical system of the automobile. As indicated in Fig. 2, it is common to have a circulation of quite a large volume of water thru the cooling system of the engine. This circulation is usually brought about by means of a small pump which forces the water thru the various parts of the motor and then thru the radiator where the heat is given off. In the lubricating system the oil is usually forced thru small tubes by a small pump to the various surfaces to be kept lubricated. These processes are readily understood in most cases.

In these cases of circulation of a liquid it will be seen that several things are fundamentally necessary. In

the first place, a pump or other means of causing pressure, or circulation of the liquid, must be provided. A suitable path thru which the liquid can flow must also be provided, which in the case of the water includes the openings in the motor parts, the tubes connecting the motor, or engine, parts to the radiator and the openings in the radiator. In the case of the oil, the paths may be made up of small tubes and most of the oil may return in various ways to the crank case.

The applications of electricity resemble these common water and oil applications in many ways. An electrical current is electricity in motion just as a water current is water in motion. The producing, leading, and controlling of electrical currents form the basis of electrical work.

In this connection it must be understood that several requirements must be met, as in the case of either of the other applications, before it is possible to cause an electrical current to flow. These requirements may be stated briefly as follows:

1. Electrical pressure, or voltage, must be provided.
2. A complete conducting circuit, or path, must be provided from the source of pressure to the point, or points, where the electricity is to be used, and back again.
3. Suitable provision must be made for controlling the current.

3. Electrical Pressure, or Voltage.—Just as a pump or storage tank is necessary to force liquid to desired points, so is it necessary to provide some means of forcing electricity. This pressure in electrical work is

called voltage or electromotive force and is commonly supplied by dry cells, storage batteries or generators, see Fig. 3. When one connects a wire to any of these sources of pressure he is doing the equivalent of connecting a hose to a faucet.

4. Circuits.—Water will flow out the end of a hose but electricity will not flow out the end of a wire con-

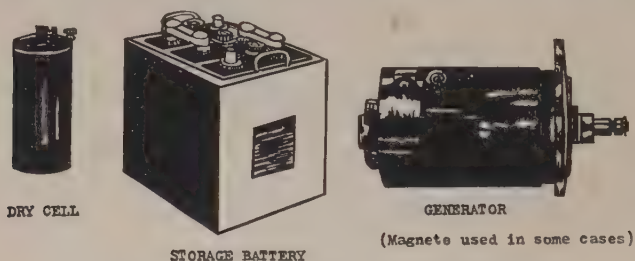


FIG. 3. Common sources of electrical pressure.

nected to a battery or generator. On a faucet there is but one connecting point; on a dry cell, storage battery or generator there are always two. Two connections must always be made before it is possible for an electrical current to flow in a circuit. A circuit is a complete electrical path leading from the source of pressure to the desired point and back to the source. Circuits are indicated in Fig. 4. The path for the electricity must always be provided by means of materials which are capable of carrying or conducting it. However, openings are not necessary as for liquid because electricity will flow thru a solid piece of material if the material is a conductor. Common conducting materials include metals, carbon and solutions of salts and acids. Thus electrical circuits may be provided with metal wires, or pieces of any shape; or in certain cases

with carbon; and the current may pass thru solutions of salts or acids.

5. Suitable Provision for Electricity.—A source of electrical pressure and an electrical circuit are absolutely necessary for the flow of an electrical current, but certain requirements must be met in both cases. This is true also of liquid circuits. The pump must be

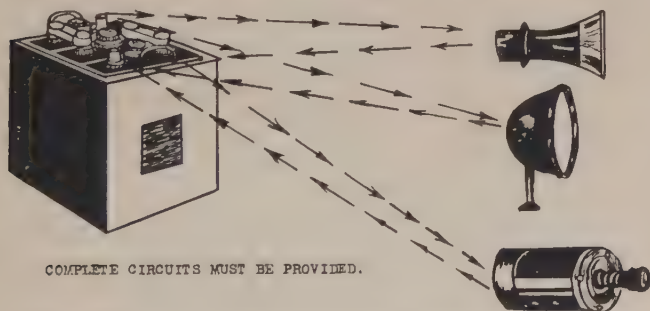


FIG. 4. Illustrating what is meant by complete circuits.

capable of furnishing the right pressure; it must be large enough to permit a sufficient amount of liquid to pass thru it; the pipes, or tubes, must be sufficiently large, and they must be made of material such that they will withstand the forces acting upon them. Among the specific requirements for any given electrical application are the following:

1. The pressure, or voltage, must be suitable.
2. The source must have current capacity sufficiently large.
3. The conductors used in the circuit must be sufficiently large.
4. The conductors must be properly covered and insulated.

6. Suitable Voltage.—Voltage, or electrical pressure, which causes electricity to pass thru properly provided circuits, must be suitable for any given purpose. Just as a pressure of a few pounds per square inch, or perhaps only a fraction of a pound, may be suitable for some purpose and higher pressures may be suitable for other purposes, so must electrical pressure be adapted to particular needs. In the case of gasoline automobiles voltages of 6 and 12 have been most common while in other cases they have been much higher. In the majority of cases in automobiles the voltage is about 6.

This matter of voltage is highly important in that electrical devices of any kind must be so constructed as to withstand the voltage impressed upon them just as a high-pressure apparatus must be somewhat different from that to be used for low pressure. Thus, electric lamps marked 6-volts are suitable for use on a 6-volt source of pressure and should not be connected to sources giving a greater pressure than 6. On the other hand, if a lamp of this kind is connected to a source of pressure less than 6 it will not get sufficient current and will not light up to its full brilliancy, if at all.

7. Sufficient Current.—For carrying on any electrical application, a certain amount of electrical energy is required. In the case of the radiator circuit a certain amount of work must be done in supplying the circulation of a sufficiently large current of water to keep the engine cool; and in the oil system the circulation of sufficient oil is necessary to keep the various parts properly lubricated.

Whenever a lamp is being used, whenever a horn is being operated, or whenever any part of an electrical system is in use, electrical power, or energy is being used. The unit by which electrical power is measured is the watt. Thus anything making use of 10 watts requires twice as much power as does one using 5 watts. It is evident, then, that since it is much more difficult for the starting motor to turn the engine over than for the small horn motor to do its work, the starter will use a much greater amount of electrical power than will the horn motor if both are operated for the same length of time.

Now electrical power depends upon two things, the voltage and the current. Pressure alone will do nothing. A battery when idle with nothing connected to it if tested with a volt meter will indicate voltage, or pressure, but it is of no use until it is connected to a circuit and an electrical current is forced to flow. It is necessary to have a flow of electricity with a pressure back of it in order to get any effect. To make this clear, consider Fig. 5.

A tank of water in which there is considerable pressure but no opening thru which the water can flow is not capable of furnishing power. The only way in which this could be made serviceable for power pur-

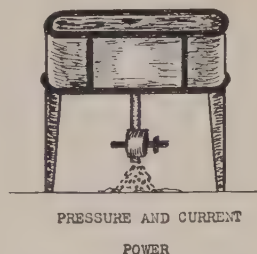


FIG. 5. Power is delivered only when there is pressure and current.

poses would be to drill a hole and attach a pipe to the tank. The power then would depend upon the pressure and the rate at which the water would flow out.

Likewise in electrical applications pressure and current flow are necessary and the greater the amount of power used, the greater must be the current if the same pressure is used. The starting motor will, therefore, draw a much larger current than will the horn motor or a lamp.

Electrical currents, or the rates at which electricity flows in circuits, are measured by a unit known as the ampere. That is, electricity flows twice as fast thru a thing that draws 2 amperes as thru one that draws 1 ampere. It is evident, then, that a sufficiently large number of amperes will be necessary for carrying on any given electrical activity.

8. Sizes of Wires.—It has been previously stated that for the flow of an electrical current, an electrical pressure and a complete circuit are necessary. In connection with the provision of the complete circuit points other than simply forming the circuit must be taken into consideration.

Let us consider for a moment the cooling-water circuit and the oil circuits. The radiator may be connected to the engine by two pieces of large hose and the various oil tubes may be made of copper tubing. No one would think of attempting to use the hose in place of the tubes or the tubes in place of the hose. Likewise in electrical circuits certain points must be taken into consideration in the selection of the parts of the circuit. Among these points are the following:

1. Electricity is not forced with the same ease thru all kinds and sizes of conducting materials.

2. It is more difficult to force current thru long wires than thru short ones.

3. It is more difficult to force current thru small wires than thru large ones.

The tendency of a conductor to hold back the electric current is called resistance. It is the resistance of the circuit that determines the current that can be forced thru the circuit by a given pressure. That is, if anything having a high resistance is connected to a battery, a small current will be forced thru it, but if something having a low resistance is connected, a large current will flow thru it. There is a definite relationship existing between the voltage, amperage and resistance known as Ohm's law. By the use of this relationship any one of these three values can be determined if the other two are known. This law is usually given as I equals E divided by R , where I represents amperes, E represents volts, and R represents resistance which is expressed in ohms. The number of amperes equals the voltage divided by the number of ohms resistance; the voltage equals the amperes multiplied by the ohms resistance; and the ohms resistance equals the voltage divided by the amperes. These relationships are often found convenient when it is desirable to determine any of these values. In connection with this it might be mentioned also that power, or watts, is represented by voltage and amperage, or pressure and current, which would be $E \times I$. Thus volts multiplied by amperes gives watts. If the number of watts required by any device is known it is possible to determine the current it will

draw by dividing the watts by the voltage. Other applications of these relationships may be used also.

To illustrate applications of the above relationships, suppose a coil known to have a resistance of 3 ohms is to be used in connection with a 6-volt battery and it is desired to determine how many amperes will flow thru it. Applying Ohm's law, I equals E divided by R , or amperes equal volts divided by ohms, we find that putting 6 in place of E and 3 in place of R gives I equal to $6/3$ or 2. Thus 2 amperes would be forced thru the coil.

Now, suppose that it were known that the coil mentioned required a current of 2 amperes and it were desired to determine what the voltage must be. Applying the law again we see that E equals $I \times R$ or 2×3 which is 6. Thus we determine that a pressure of 6 volts will be necessary to force 2 amperes thru a coil having a resistance of 3 ohms.

Taking the same example again, suppose that it were desired to determine the resistance which would be necessary to hold the current to 2 amperes under a pressure of 6 volts. Applying the law in which we find R equals E/I , the resistance necessary equals $6/2$ or 3 ohms.

Thus we see that Ohm's law can be applied in cases of actual numerical values in determining by mathematics unknown values when two others are known; but the value of a knowledge of this law is not limited to this alone. It is valuable in a general way in assisting one in reasoning what can be expected when certain conditions are brought about. For example, from the standpoint of the law let us consider what would take

place if a 6-volt lamp were connected to a 12-volt source. The resistance of the lamp filament is approximately the same at all times except at just the instant at which it is supplied with current. Thus R will be the same in both cases. Let us assume that it is 6 ohms. Now I equals E/R which in the case of the 6-volt source will be $6/6$ or 1 but in the case of the 12-volt source it will be $12/6$ or 2. Thus 2 amperes would be forced thru the lamp filament and if it were designed to carry only 1 ampere it would burn out. With this in mind, it will be seen that when any device of given resistance is connected to a source of pressure the current will vary directly as the pressure. That is, if the voltage is doubled the current will be doubled, etc.

Consider now, for an instant, that a 6-volt storage battery is used for two certain devices, one having a resistance of 3 ohms and the other 6 ohms. I , or the amperes, in the case of the first will be $6/3$ or 2, and in the case of the second $6/6$ or 1. Thus we see that when the voltage is constant, the current varies inversely as the resistance. That is, if the resistance is doubled the current will be reduced one-half, etc.

Considering applications of the law still further we see that voltage equals current $\times$ resistance or E equals $I \times R$. This is an important relationship. For example, assume that at the terminals of a storage battery the voltage is 6 and that two large wires lead from the battery to the starting motor. Let us assume that the resistance of the wires is $1/100$ ohm and that the motor requires 100 amperes. Then E equals $100 \times 1/100$ or 1. This represents the voltage required to force the current thru the wires alone and 6—1 or 5 volts is the

pressure left to force current thru the motor. Now suppose that in another case smaller wires are used, the resistance of which is 2 100 ohm, and that the current is 100 amperes. Then E equals $100 \times 2 / 100$ or 2. This would leave 6—2 or 4 volts as the pressure available for forcing current thru the motor. Thus the greater the current and the greater the resistance in the circuit wires leading to a device, the greater will be the drop in voltage due to them. This partly explains why the wires leading to the starting motor must be large and the resistance low and it gives a general idea of the effect of the circuit wires in cutting down the voltage available at the terminals of a device.

Applying Watt's law, which is watts equal volts $\times$ amperes, or amperes equal $\frac{\text{watts}}{\text{volts}}$, or volts equal $\frac{\text{watts}}{\text{amperes}}$, assume that a device requires 12 watts of power and that it is for use on a 6-volt battery. If it is desired to determine the number of amperes it will draw, this can be done by dividing 12 by 6 which gives 2. If the device were designed for use on a 12-volt battery, the current would be 12/12 or 1 ampere. Thus a device requiring a given amount of power will draw a current which varies inversely as the voltage. That is, if the voltage is doubled, the current will be reduced one-half, etc.

Forcing an electrical current thru a high resistance causes heat which in the case of lamps or heaters is desirable, but in connecting various things, it is evident that the conductors should be sufficiently large to eliminate the possibility of cutting down the current or

causing excessive heating. Thus, the wire, or cable, connecting the storage battery to the starting motor must be large because it must carry a very large current which would probably be sufficient to burn a small

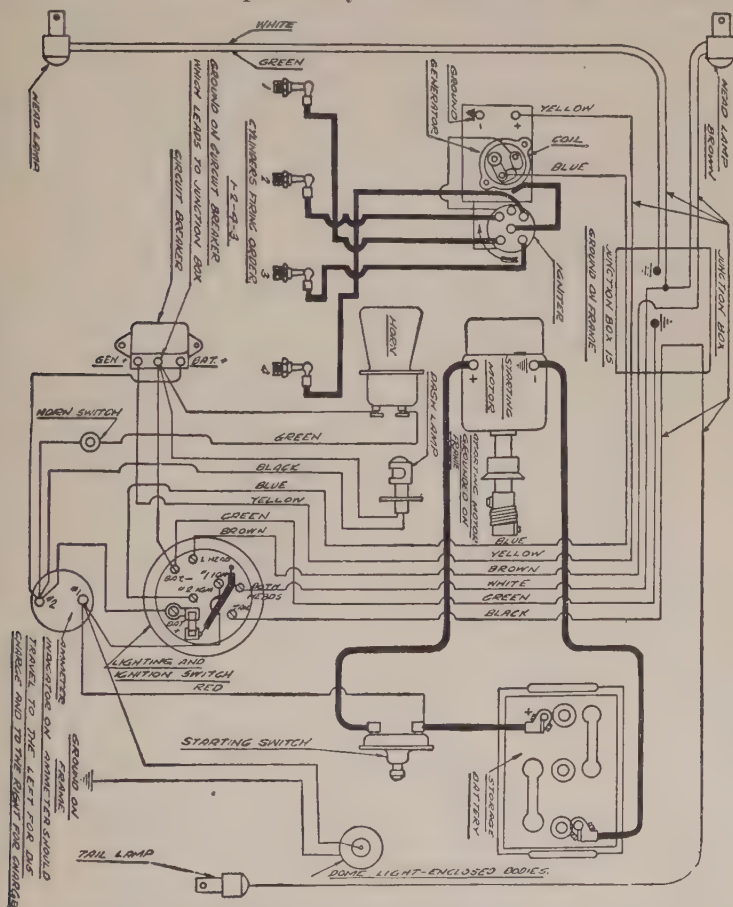


FIG. 6. The cables to the starting motor must be large to carry the required current. The spark-plug cables must be heavily covered to withstand the pressure.

wire. See Fig. 6. Other wires which are required to carry only small currents may be comparatively small.

9. Coverings and Insulators.—In an automobile electrical system such as indicated in Fig. 6, the large number of conducting paths, or circuits, would undoubtedly be unsatisfactory if the wires were not covered or if improperly insulated parts were used. These points must be taken into consideration.

Since all metals and some other materials are conductors, it is evident that it is necessary to use wires covered with materials which will not permit electricity to flow thru them, and that it is often necessary to use materials which will insulate parts of the circuits or provide suitable non-conducting supports. Common insulating materials are rubber and cotton, dry wood, paper, porcelain, glass, and mica.

In the case of the cables leading to the spark plugs, ordinary coverings are not sufficient because the voltage is extremely high. For this reason wires with very heavy coverings are used. See Fig. 6.

The application of many of these principles will be noted in the study of the parts and workings of the electrical devices commonly used and they should be kept in mind whenever an electrical application of any kind is being considered.

QUESTIONS ON CHAPTER I

1. Of what particular value is a knowledge of the laws of electricity?
2. Name at least three important uses of electricity in the automobile.
3. What two common circulating systems in the automobile can be compared with an electrical system?

4. What are the three fundamental requirements for any electrical application?

5. What is electrical pressure called?

6. How is electrical pressure commonly supplied?

7. What is meant by an electrical circuit?

8. Name three materials that have the property of conducting electricity.

9. Give four requirements which must be met for the proper application of electricity in any specific case.

10. Explain what we mean when we say the voltage must be suitable.

11. Why is it important to know what the voltage is?

12. What voltages are commonly used in automobiles of the gasoline type?

13. Which will require a greater current of electricity, the starting motor or the horn? Why?

14. What is the unit by which electrical power is measured?

15. What is the unit by which electrical current is measured?

16. What in the cooling system and the oiling system are similar to the wires in an electrical system?

17. Give three important points which must be taken into consideration relative to the kind and size of conductors for an electrical circuit.

18. What is meant by resistance?

19. What unit is used in measuring resistance?

20. If a coil of wire having a resistance of 2 ohms is connected to a 6-volt battery, how many amperes will flow thru it?

21. If a certain device requires 10 watts of power, how many amperes will it require from a 6-volt storage battery?

22. What would be the resistance of the above device?

23. If the resistance of a coil is 2 ohms and it requires a current of 3 amperes, what must be the voltage of the battery or generator to which it should be connected?

24. What happens if electrical current is forced thru a small wire having a very high resistance?

25. What must be considered when determining the relative sizes of wires to be used in an electrical circuit?

26. Which wires must be larger, those running to the starting motor or those running to the horn? Why?
27. Why are coverings and insulating materials necessary?
28. Make a list of at least five covering or insulating materials.
29. Why are the wires leading to the spark plugs heavily covered?

CHAPTER II

ELECTRICAL PRESSURES; STORAGE BATTERIES

10. Sources of Electrical Pressure.—In the foregoing chapter it has been pointed out that one of the fundamental requirements for electrical applications of any kind is the provision of suitable electrical pressure, or voltage. For automobile work the common sources of pressure are dry batteries, storage batteries, magnetos, and generators. Of these sources the dry battery and the storage battery depend for their action upon chemicals while the magneto and generator have for their basis of operation magnetism and induction. In this present discussion the former will be taken into consideration. The latter will be covered fully after a discussion of the electrical phenomena upon which their action depends.

11. Dry Cells.—A dry cell consists, essentially, of a zinc can, or container, in which are a carbon stick and suitable chemicals for causing a chemical action to take place during which the zinc is gradually used up as are also the chemicals. The taking place of this chemical action, when suitable connection is made outside of the cell between the carbon and the zinc, causes an electrical current to flow from the zinc to the carbon inside of the cell and from the carbon to the zinc outside of the cell.

Now the magnitude of the current, the number of amperes, depends upon the total resistance in the circuit (Sec. 8.) That is, it depends upon the resistance of the materials inside of the cell and the resistance

in the circuit outside of the cell. It depends upon the voltage also, but all dry cells regardless of their size give a voltage of about 1.5. It is evident, then, that the electrical current which a dry cell is capable of furnishing will depend very largely upon the resistance of the chemicals inside of the cell. This is an important point to remember.

12. Limitations of the Uses of Dry Cells.—It has been stated in the previous chapter that for any electrical application suitable pressure and a sufficiently large current must be provided. That is, the voltage and the amperage must be suitable. A single dry cell gives a pressure of about 1.5 volts when the materials are in good condition and it is capable of causing a current of about 20 amperes to flow thru a short heavy wire connected directly across its terminals. Whenever any piece of electrical apparatus is connected to the dry cell, however, the number of amperes will be less than this amount depending upon the resistance. Also, as the cell is used the resistance of the chemical combination within it, or its internal resistance, increases. Then, too, when the current flows thru the cell, certain chemical actions take place which cause the formation of bubbles of gas tending to obstruct the flow of electricity if a large current is drawn for any length of time.

The dry cell may be compared, in a way, with a small tank of water in which there is a comparatively small opening thru which the water can flow, the water containing a certain amount of sediment which gradually collects on the inside of the opening and lessens the flow. See Fig. 7. Then, too, the dry cell becomes value-

less as soon as the zinc and the chemicals have been used up and it must be replaced with a new one.

13. Methods of Connecting Dry Cells.—If it is necessary or desirable to use dry cells, several cells may be connected to form what is commonly known as a battery. Increased voltage may be obtained by connecting the cells in series, and increased current may be obtained by connecting them in parallel. Dry cells are connected in

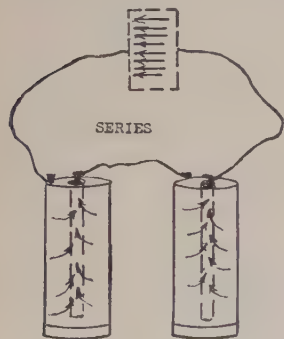


FIG. 8. Two dry cells connected in series. All of the current passes thru each one.



DRY CELL



LIMITED QUANTITY
LIMITED RATE

FIG. 7. The dry cell may be compared to a small tank of water with a limited outlet.

series when the unlike terminals are connected; that is, the carbon of one to the zinc of the next, etc., as in Fig. 8. They are connected in parallel, or multiple, when the like terminals are connected; that is, the carbon of one to the carbon of the next, the zinc of the one to the zinc of the next as in Fig. 9. When two or more cells are connected in series the voltages are added; that is, two cells in series will give about 3 volts, three will give about 4.5 volts, etc. It will be seen that when this is done the current will be decreased because it must be forced thru all of the cells. However, if they are connected in parallel, or multiple, the voltage will be

carbon of the next, the zinc of the one to the zinc of the next as in Fig. 9. When two or more cells are connected in series the voltages are added; that is, two cells in series will give about 3 volts, three will give about 4.5 volts, etc. It will be seen that when this is done the current will be decreased because it must be forced thru all of the cells. However, if they are connected in parallel, or multiple, the voltage will be

unchanged but the current capacity will be increased. Two cells connected in multiple will have a greater current capacity because two paths are furnished for the current thru them. Various combinations of series and parallel connections give voltage and cur-

rent capacities which are satisfactory for certain kinds of applications.

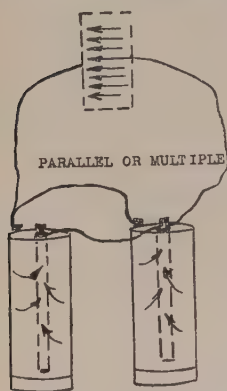


FIG. 9. Two dry cells connected in parallel. One-half of the current passes thru each one.

14. Storage Batteries.—Storage batteries such as shown in Fig. 10 differ considerably from dry batteries, the two chief characteristics which make them particularly valuable being (1) they can be charged and recharged time after time, and (2) they are capable of furnishing large currents. Where the dry cell may be compared with a small tank in which there is but a limited opening, the storage cell may be compared with a tank which can be

kept full of water and out of which the bottom can be dropped temporarily if necessary. These characteristics of the storage cell make it so desirable for use in the automobile where it can be charged by the generator and in which it can be used for furnishing the large current such as required for the starting motor that it is of very great importance and will be discussed somewhat in detail in the following paragraphs.

15. Parts and Assembly of the Storage Battery.—A simple storage battery or cell can be made by placing

two pieces of lead in a weak solution of sulphuric acid. If such an arrangement is provided and connected to a dry battery or low-voltage generator, a chemical action takes place and one of the pieces of lead turns brown. If the battery is disconnected after this action

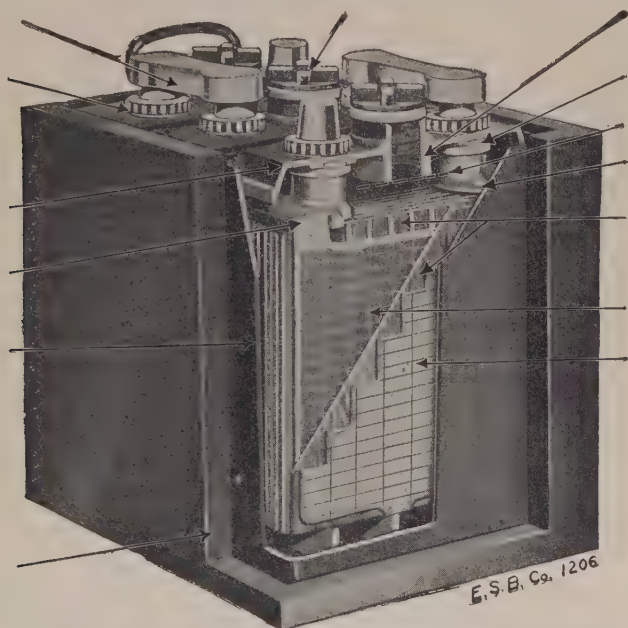


FIG. 10. A typical storage battery (Lead-sulphuric acid type).

has taken place for a considerable length of time, it will be found that the storage cell will furnish an electrical pressure which will ring a bell or operate an electromagnet. If this pressure is measured with a voltmeter it will be found to be about 2 volts.

Commercial storage batteries are made and assembled as indicated in Fig. 11. Active materials, lead

PARTS AND ASSEMBLY OF A TYPICAL PORTABLE STORAGE BATTERY
 — LEAD-SULPHURIC ACID TYPE —

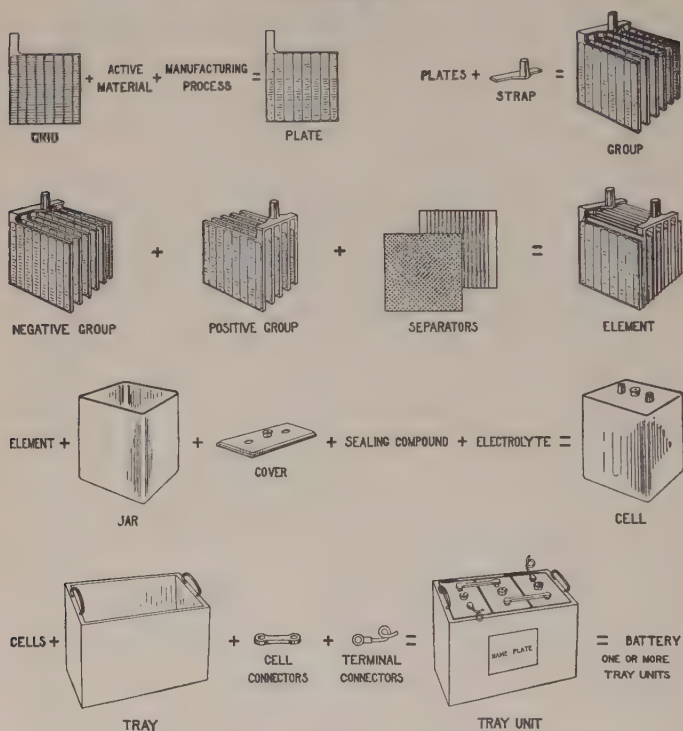


FIG. 11. Parts and assembly of a typical storage battery.

chemicals, are placed in grids and made into what are commonly known as plates. There two kinds of plates, positive and negative, the former being lead peroxide which is brown and the latter being sponge lead which is grey in color. Several plates are mounted on a strap to form what is commonly known as a group. (The current capacity of the cell depends upon the size and number of the plates.) A group of negative plates and

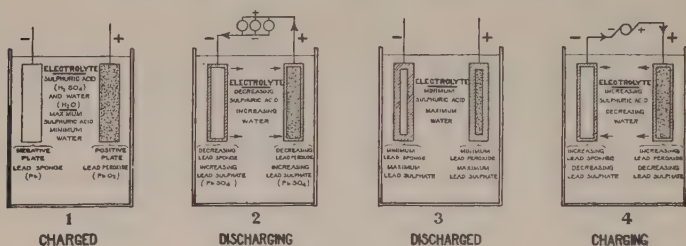
a group of positive plates placed together with separators between the individual plates form what is known as an element. The element is placed in a jar. A cover is placed on the jar and sealed. Electrolyte, dilute sulphuric acid, placed in the jar forms a complete cell which is capable of furnishing a pressure of about 2 volts and a comparatively large current, the value depending upon the area of the plates and their number. The most commonly used storage battery is one giving a pressure of 6 volts which can be obtained by connecting three cells in series. Therefore, a complete battery is formed by placing three cells in a tray, or box, and connecting them with cell connectors, the negative of one cell being connected to the positive of the next, etc. This completes the storage battery unit which is so largely used in automobile work and to which connections are made by means of terminal connectors which fit onto the posts on the straps of the first and last cells.

It will be noticed that the groups of plates are in reality plates connected in parallel, or multiple. Each plate provides a path for the electricity and consequently the electricity will flow thru with little resistance holding it back. Plates connected this way are equivalent to one large plate of the several plates combined. Thus we see the reason why the current capacity of the storage battery is so great.

16. Chemical Action in a Storage Cell.—In Fig. 12 is indicated the chemical actions taking place in the cell from the time it is charged thru the time that it is discharged and recharged. When the cell is fully charged, the negative plates are all sponge lead of a grey color

and the positive plates are all lead peroxide of a brown color, and the sulphuric acid solution in the cell is the "strongest" or most concentrated. Lamps, or other load, drawing current thru the cell cause a reduction of the sponge lead and the lead peroxide and the for-

CHEMICAL ACTION IN A CELL ON CYCLE OF DISCHARGE AND CHARGE



CHEMICAL EQUATION

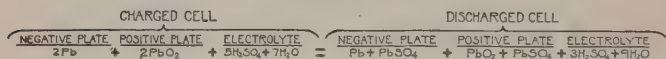


FIG. 12. Illustrating the chemical action in a cell during discharge and recharging.

mation of lead sulphate, a white solid, on both sets of plates. At the same time the acid solution becomes "weaker" or less concentrated. If this load is carried for a sufficient length of time, the cell becomes discharged and the acid solution becomes the "weakest" and there is a large quantity of lead sulphate on the plates. As the charging process is begun, current furnished to the cell, the lead sulphate starts to disappear, the acid starts to get "stronger," and the plates begin to go back to their original form.

17. Care and Operation of a Storage Battery.—The storage battery in an automobile requires attention

which is very simple but of very great importance. If the battery is given this attention, it may in some cases last twice as long as if it were neglected. This simple but important attention includes:

1. Examine, test, and fill and wipe off the battery once a week.
2. Keep the connections tight and covered with vaseline.
3. Keep the filling plugs tight and the battery dry and clean.
4. Do not permit the battery to remain discharged.
5. When storing the battery or putting it into service, do so in the proper manner.
6. Do not permit the battery to become overheated.

18. Examining and Testing a Storage Battery.—If a storage battery fails to function properly it is necessary to examine and test it, but, even tho no trouble is apparent, possible trouble may be avoided by proper examination and testing. It is well to keep on the lookout for loose or dirty connections, corroded terminals, and the like.

For testing a storage battery the most common instrument is the one known as a hydrometer syringe. This is essentially a glass tube in which is placed a small instrument with graduations on it which read 1.100, 1.200, etc., with the subdivisions between these; a bulb on one end of the tube; and a small tube on the other end. See Fig. 13. The hydrometer is used to test the "strength" of the solution in the cells of the

storage battery. This is commonly known as specific gravity which is used as a means of comparing the weights of equal volumes of various liquids. The heavier a liquid, the greater will be its specific gravity.

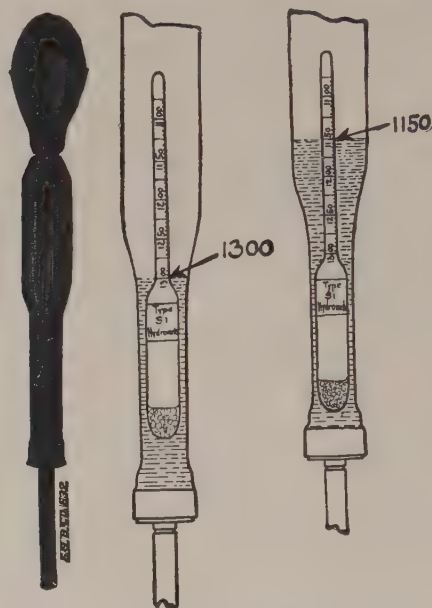


FIG. 13. The hydrometer and its readings when the battery is charged and when it is exhausted.

The hydrometer is used in the following manner: (1) Remove the vent plug from the cell. (2) Insert the rubber tube into the cell so that the end of the tube is below the level of the solution. (3) Squeeze the rubber bulb and release slowly drawing the solution into the chamber until the hydrometer floats. (4) Take the reading level of the solution. (5) Return the solution to the cell. This is illustrated in Fig. 14.

The reason why this gives an indication of the charge in the battery is not difficult to understand. Referring to the description of the chemical action in the cell during charge and discharge, we see that when a cell is fully charged there is a maximum amount of sulphuric



FIG. 14. Illustrating how a hydrometer reading is taken.

acid in the electrolyte and as the charge of the cell decreases, the solution becomes weaker, until when the cell is nearly discharged the electrolyte contains a minimum of acid and a maximum of water. Now sulphuric acid has a specific gravity of 1.835 while that of water is 1.000. It is evident then that the greater the amount of acid in the electrolyte the greater will be

the hydrometer reading; and since the proportion of sulphuric acid indicates the charge in the cell the greater the hydrometer reading, the greater the charge in the cell. A cell is considered fully charged when the hydrometer reads 1.300, and fully discharged when it reads 1.150. If the reading is found to be less than 1.250 the battery charge is too low and should be increased.

There are other methods of testing storage batteries with meters but the hydrometer test is by far the most widely used.

19. Keeping the Storage Battery Properly Charged.
—On most automobiles a generator is provided which is operated by the engine and which ordinarily keeps the battery charged. An ammeter is usually connected in this circuit and placed in view of the driver so it is possible to tell whether or not the battery is being charged.

One may avoid running down the storage battery if he will observe the following: Short runs and frequent stops requiring the use of the starting motor, or using the car largely at night so that the lamps use up more current than is furnished by the generator may cause an undercharged condition. The exhausting of the battery may be avoided by refraining from using the starting motor more than is absolutely necessary, by not using the horn excessively, and by using the lights economically. If the battery is not too badly undercharged, the remedy is to drive the car a good distance at a good rate of speed. Sometimes, however, the automobile is not driven sufficiently to keep the battery properly charged and sometimes other conditions arise

which make necessary the charging of the battery from some source other than the generator on the car. When this is done, the following are of importance:

1. Direct current must be used.
2. The positive of the battery must be connected to the positive of the source.
3. The rate of current flow must be properly regulated.

The details of this work will be covered later.

20. Adding Water to the Battery.—The solution in a battery, or the electrolyte as it is called, is a mixture of pure water and sulphuric acid. Water evaporates; sulphuric acid does not. Then, too, the solution in a battery sometimes gasses or bubbles when the battery is being charged. These bubbles are gas which come from the water as it is broken up by the electrical current. The acid is not affected. It is evident, therefore, that it is necessary to add pure water at times to make up for this loss. It is not necessary to add acid however. In fact, acid should never be added to replace evaporation.

Water should be added often enough to keep the plates covered. It will be required more frequently in the summer than in the winter. The water which is suitable for use in the storage battery must be free from all impurities which might be injurious. Distilled water is best but rain water which has not come in contact with metal of any kind may be used. Distilled water is not boiled water but that which is formed when steam condenses after it has been formed by boiling. All water for battery use should be kept in clean, cov-

ered vessels of glass, china, earthenware, rubber or lead.

In the winter when there is freezing weather, water should be added before using the car and not after. The reason for this is that water being lighter than acid will remain on the top of the solution until it is mixed by the action of the battery. If not mixed with the solution, it will freeze almost as quickly as if it were outside the battery.

21. Battery Cleanliness.—It is important to keep the battery dry and clean because dampness or dirt on it permits current to leak away and holds small quantities of battery solution which in time cause corrosion of the terminals or rotting of the case. If the battery becomes wet, before drying it, go over it with a rag dampened with ammonia solution. The ammonia will counteract the effect of the acid solution.

Battery connections are made of metal parts heavily coated with lead but if the metal becomes exposed, corrosion may appear. This is often a white, greenish, or bluish color. To guard against it the terminals should be covered with vaseline. This will not interfere with the conducting of the electrical current and will provide protection against the action of the acid if there is any present.

The filling plugs should be kept tight so to avoid spraying out of the solution when charging.

22. The Effect of Leaving a Battery Discharged.—A battery should not be left in a discharged condition because of the detrimental effect upon the plates. In Sec. 16, the chemical action in the cell during discharge has been shown to produce large quantities of lead sul-

phate on the plates. If the battery is left in this condition the lead sulphate offers considerable resistance to the flow of electrical current thru the battery. This increased resistance is liable to cause excessive heating which may cause the plates to "buckle." When a battery gets in this sulphated condition special care must be taken to give it a charge at a low rate to avoid overheating.

23. Storing a Battery or Putting it Into Service.—

When a car is to stand idle for a considerable period of time or when it is laid up for the winter, the battery must be properly stored if it is expected to remain in the best condition. Unless a battery is in such condition that it will require dismantling and repairing before it is again put into service, it may be put away in what is called "wet storage." When putting a battery in wet storage it should be placed on a shelf or a convenient place large enough to allow a little air space around it. It is well to place it upon wooden strips to provide air circulation and to avoid rotting of the case. Vaseline should be applied freely to the terminals to avoid corrosion. The location of the battery should be clean and the temperature should be above freezing but below 110 deg. Fahrenheit.

Once every month the filling plugs should be removed, distilled water added, and it should be charged for four or five hours.

When the battery is put back into service, water should be added and it should be charged.

24. Avoid Over-Heating.—Over-heating of a storage battery is the cause of many battery troubles. It causes buckled or warped plates which often render the bat-

tery practically useless. The most common cause of over-heating is failure to keep the battery filled with distilled water. When the plates are completely covered with electrolyte their entire surface forms a passage for the electrical current that passes thru the battery. If, however, only one-half of the surface of the plates is immersed in the solution this area must carry the same electrical current, or perhaps twice as much per square inch of plate. We know that this would increase the tendency to heat up.

Over-heating may be caused also when an attempt is made to charge a battery in which the plates have become sulphated. This was discussed in Sec. 22.

In addition to the above, driving a car a long distance, especially during hot weather, may cause excessive heating. The generator in an automobile is designed to furnish sufficient current to take care of average conditions. If, however, conditions such as brought about by long vacation trips, and the like, may cause the generator to furnish more current than is required to fully charge the battery. If this is the case, the battery may become over-heated. To guard against such a possibility it is well to take temperature readings or indications of the battery or to examine it carefully at times when it might become over-heated and to drive with the lights turned on. This will use the current and keep it away from the battery. The temperature of a battery should never be over 110 deg. F.

QUESTIONS ON CHAPTER II

1. Name four sources of electrical pressure.
2. Which of these depend for their action upon chemicals?
3. Upon what do the others depend?
4. Give a brief description of a dry cell.
5. Upon what does the current which a cell is capable of furnishing depend?
6. What is the approximate voltage of a dry cell?
7. About what is the maximum current which a dry cell is capable of furnishing?
8. Give two reasons why the use of dry cells in automobile work is limited.
9. How can dry cells be connected to increase voltage?
10. How can dry cells be connected to increase amperage?
11. Make a sketch of two cells connected in series.
12. Make a sketch of two dry cells connected in parallel or multiple.
13. What two chief characteristics of the storage battery make it suitable for use in the automobile?
14. How is it possible to make a simple storage cell?
15. Name the parts that go to make up a storage cell group.
16. What two kinds of plates are there?
17. Explain what is meant by an element.
18. Of what does a storage cell consist?
19. Of what does a complete battery or tray unit consist?
20. What is the voltage of a typical storage cell?
21. Upon what does the current capacity of a cell depend?
22. Explain why a storage cell is capable of furnishing a large current.
23. What is the condition of the plates and electrolyte when a cell is fully charged?
24. As a cell is discharging, what takes place?
25. In what direction does the current flow outside of the cell during discharge?
26. In what direction inside of the cell?
27. What takes place within the cell when it is being charged?

28. In what direction must the current flow into a cell when charging?

29. State six important considerations in taking care of a storage battery.

30. Explain how to test a storage battery with a hydrometer.

31. How does the hydrometer give an indication of the state of the charge in the cell?

32. What is the specific gravity of the electrolyte when a cell is fully charged? When discharged?

33. Above what point of specific gravity should the electrolyte be kept?

34. How is it possible to avoid running down a storage battery?

35. If a storage battery must be charged, what three things must be remembered in connection with this?

36. Why and how often should water be added to a storage battery?

37. What kind of water should be used?

38. In what kind of a vessel should it be kept?

39. Why is it important that the battery be kept clean?

40. What may be used on battery terminals to prevent corrosion?

41. Why is it important to avoid leaving a storage battery in a discharged condition?

42. How may a storage battery be stored satisfactorily?

43. What care should be given it while in storage?

44. Why is it necessary to avoid over-heating a storage battery?

45. How can over-heating be avoided?

CHAPTER III

STORAGE BATTERY WORK

25. Several Branches of Storage Battery Work.—

Storage battery work alone forms the basis for many industries. Not only are there many processes involved in the manufacture of batteries but also are there many involved in their maintenance and repair. It is impossible to cover all of these in this text but some may be discussed rather briefly. Those to be covered at this time may well include cleaning, charging, and repairing.

26. Cleaning Storage Battery Terminals.—As has been stated, storage battery terminals may become corroded if proper precautions are not taken. This corrosion may cause the resistance of the terminals to increase and this we know would interfere with the flow of current. If this corrosion has taken effect, the battery may be slow to charge or it may not operate the starting motor.

A solution of ammonia or a mixture of baking soda and water, about 6 tablespoons of soda to one-half a pint of water, may be used. When removing corrosion all washers, nuts, etc., should be removed and put into the solution and left there for from fifteen minutes to half an hour. This will loosen the corrosion which may be removed with a short stiff brush. In extreme cases the corrosion may have to be scraped off. When cleaning the terminal posts a piece of waste should be placed at the base to keep the solution from getting into the battery. After the corrosion has been re-

moved, the terminals should be given a thin coat of vaseline.

27. Charging a Storage Battery.—From our previous discussion of the characteristics and operation of the storage cell, we have found that the charging process is simply one of forcing an electric current thru the battery cells to cause certain chemical actions. When doing this, the following must be taken into consideration: direct current must be used; the positive of the battery must be connected to the positive of the source and the rate of current flow must be properly regulated.

28. Direct Current Must Be Used.—The first important consideration is the kind of current required. There are two general kinds of current known as alternating current, often represented by A.C., and direct current, often represented by D.C. Alternating current changes in direction at certain close intervals, flowing first in one direction and then in the other, but direct current flows continuously in one direction. It is evident that alternating current would not cause the continuous chemical change required in charging the storage battery.

29. How to Tell Whether Current Is Direct or Alternating.—The majority of power companies, for economic reasons, furnish alternating current and consequently the electrical current in a city home is usually alternating. Direct current is always delivered by batteries and by D.C. generators. If the generator is available for inspection, one can usually tell whether or not it is D.C. by examining the nameplate. Then, too, one can judge somewhat by the appearance of the machine. A.C. generators, other than magnetos, are

not very common in small sizes; and D.C. generators always have a commutator and brushes. Current delivered from a transformer is alternating. It may be possible to tell by holding a magnet near a lamp which is lighted. If the current is alternating the filament will vibrate but if it is direct, the filament will take a definite position and hold it. Another method is to place the wires running from the line in a glass of water containing a little salt or acid. A large number of bubbles will form around one wire if the current is direct, but if it is alternating the same number of bubbles will be formed around both wires.

30. How to Charge From a D.C. Source.—If the source of current furnishes direct current, it is necessary only to make arrangements for the proper regulation of the current and to connect the battery properly. The current should be such that the battery will not be forced to carry such an excessive current that it becomes hot. In the case of an ordinary 6-volt lead storage battery the current should never exceed 20 amperes and it should be less than this, perhaps 5 amperes. In some cases the best charging rate is given on the battery nameplate or furnished by the manufacturer. If the ampere-hour capacity of the battery is known, $1/10$ of this may be taken as the charging rate. In all cases the possibility of over-heating must be taken into consideration.

If the voltage is too high, it must be cut down by some suitable means. In many cases it is desirable to use a suitable charging resistance which can be varied. The resistance to use depends upon conditions. If there is but one battery to be charged, the

most convenient resistance, perhaps, is a combination of lamps of the proper size and rating. In Fig. 15 is shown an arrangement for charging from a 110-volt circuit. The lamps are connected in parallel. With this arrangement each lamp turned on makes an additional path for the electrical current, reduces the total resistance in the circuit, and increases the current flow-

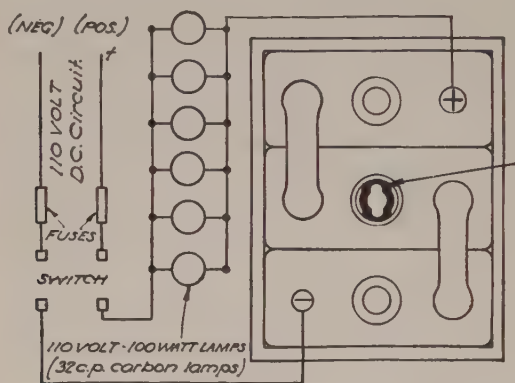


Fig. 15. Illustrating how to charge a battery from a 110-volt source.

ing into the battery. Thus, if lamps of the proper size and number are used, the desired current will be obtained.

In cases where large numbers of batteries are charged it is more economical to have a motor-generator set which consists of a high-voltage motor and a low-voltage generator which furnished voltages suitable for charging the batteries.

31. How to Connect the Battery to the Line.—It must be remembered that the positive, or plus, terminal of the battery must be connected to the posi-

tive wire of the line, or the wire which will lead the current to the battery. This is obvious when we consider that in order to reverse the chemical changes which have taken place in the battery during discharge the current must be passed thru in the opposite direction to which it flows when the battery is in use. (See Fig. 12.) Thus, when charging, the current must go in at the positive terminal and come out at the negative.

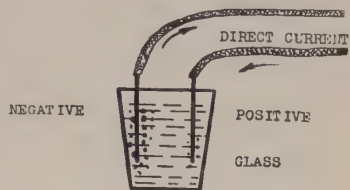


FIG. 16. Illustrating how the direction of flow of current can be determined.

The battery terminals are usually marked Pos., or plus, and Neg., or minus. If these are not marked they may be determined as described in the following section.

32. Determining Direction of the Current in a D.C. Circuit.—There are several ways of determining the direction in which current is flowing, or will flow, from a direct current source. The most simple, perhaps, is the placing of wires connected to the source in a glass of water to which salt or acid has been added. (See Fig. 16.) When this is done, current flowing thru the solution causes a chemical change during which bubbles of gas are formed. The larger number of bubbles collects at the wire leading the current out of the water, the negative.

The direction may be determined also by the use of a voltmeter. Wires leading from the meter terminals may be touched momentarily to the wires or terminals of the source. If the pointer of the meter moves in

the right direction the positive of the source is the side touched by the wire leading from the positive terminal of the meter, which is marked. If the pointer has a tendency to move backward, the connections are the reverse of what they should be. When a meter is used in this way, care should be taken to avoid bending the pointer.

33. Connecting Meters in a Circuit.—In connection with the charging of a battery it may be desirable to

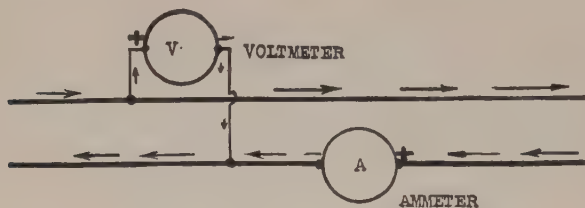


FIG. 17. A diagram showing how meters should be connected.

make use of meters. Then, too, it is often desirable to use meters for other measurements. Therefore, let us consider these for a moment.

The two meters most commonly used in this connection are the voltmeter for measuring voltage, or pressure, and the ammeter for measuring amperes, or rate of flow of current. The voltmeter, like the pressure gage on a tank or boiler, simply gives the pressure, and is connected to the two points over which the voltage is to be measured. (See Fig. 17.) For this arrangement, the upper wire leads from the source. This meter will indicate the voltage of a battery or other source if its positive terminal is connected to the

positive of the source and its negative to the negative of the source.

The ammeter which measures the flow of current must, obviously, have the current pass thru it, or it must be connected in the line in which the number of amperes is to be measured. It must never be connected to the terminals of a battery or across a line. This is because of the fact that it has a very low resistance and thru the meter alone an extremely large current would flow which would probably ruin it. The ammeter, too, must be connected in the line so that the current will flow into the positive terminal and out the negative.

34. Charging from an Alternating Current Source.

—When alternating current only is available it is necessary to provide some means of changing it to direct, or some means of “rectifying” it. In such cases, which are very common, a rectifier or motor-generator set is employed. Rectifiers of various types are used very extensively.

Rectifiers of various types are available, among which are the Tungar, the vibrating contact, and the mercury arc. The operation of these is comparatively simple and in most cases instructions are furnished. A sketch of a small Tungar rectifier is shown in Fig. 18.

35. Charging More than One Battery at a Time.—In many cases it is desirable to charge more than one battery at a time. When this is done the same principles hold as in the connecting of cells. That is, if two batteries of three cells each are connected in series, there will be a total of 6 cells or 12 volts to overcome.

Thus the voltage of the charging source would have to be something over 12. If the batteries are connected in parallel, the amount of current required for charging will need to be increased but the voltage will not.

36. Mixing Electrolyte.—In many cases it may be desirable to make up some of the solution, or electrolyte, for use in a storage battery. This solution may consist of two parts of acid to five of water, by volume. When mixing the solution, the water should be placed

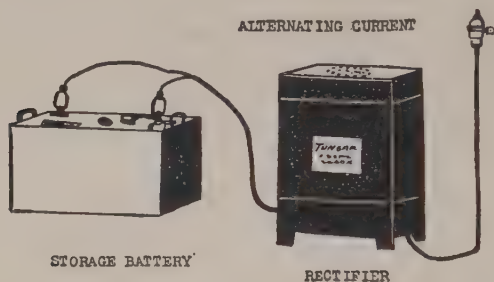


FIG. 18. A sketch of a battery being charged from an alternating current source by means of a rectifier.

in a glass or earthen vessel and the acid should be added very slowly. If the acid is poured in fast, sufficient heat may be given off to cause the vessel to break. The solution may be stirred with a wooden paddle while the mixing is being done. Always remember that *acid will burn your clothes or hands* so don't spill it.

37. Battery Repair.—Battery repair is within itself a trade, and it cannot be expected that the subject will be thoroly covered in this volume. However, some

few operations involved will probably be of interest and of value. Among these are:

1. Removing battery connections.
2. Unsealing cells.
3. Removing elements from cells.
4. Removing jars from cases.

38. How to Remove Connectors.—Connectors may be removed by boring a hole $\frac{5}{8}$ or $\frac{3}{4}$ inch in diameter, about $\frac{1}{4}$ inch deep, over the center of each post and prying them off, Fig. 19. In some cases it is possible to remove them by heating the joints with a flame, at the same time pulling the connector with a pair of pliers. If the connectors are bored, the battery should be placed in a box so as to save the metal removed.

39. How to Unseal Cells.—First clean the dirt or lead from the top of the battery, taking care not to get any in the cells. Then remove the filling plugs and blow gently into the openings to remove any gas which



FIG. 19. Battery repair: Boring connectors.

might ignite. Hand bellows may be used for this.

The sealing compound may be softened by the use of a thin-bladed knife such as a putty knife heated in

a flame and run thru the compound. Warming of the compound may be accomplished by passing a moderate flame around the cover, taking care not to hold it in any one spot long enough to burn the rubber.

When this work is done on a large scale a steam box is used. This is simply a box into which steam is forced at a low pressure. Another method is to stand the cell in very hot water, taking care that the water does not get into it.

40. How Elements Are Removed from Cells.—After the connectors have been removed and the cell unsealed, take hold of the posts with gas pliers and pull

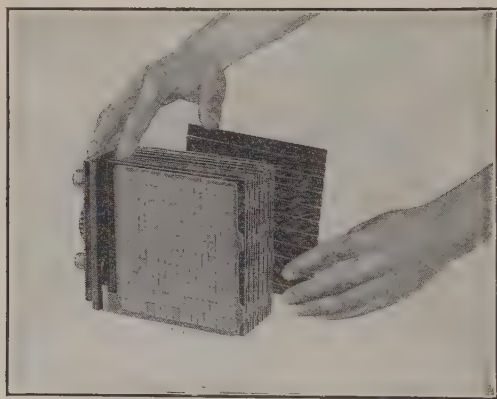


FIG. 20. Battery repair: Inserting separators.

the element from the jar. Before pulling it all the way out rest it for a few minutes on the top of the jar so the electrolyte may drain back. If the element is to be used again, place it in battery solution or water to keep it from drying out.

41. How Jars Are Removed from Cases.—After the elements have been removed the jars may be removed by heating a thin-bladed knife, such as a putty knife, working it around the outside, and lifting them out. If they stick, empty the jars and fill them with hot water. Allow them to stand a few minutes, then pull them out with pliers.

42. Assembling Batteries.—If the parts and arrangement of the battery are noted carefully as it is being taken apart, in simple cases, it will ordinarily be quite easy to make necessary repairs, do the necessary cleaning, and put the parts back together, Fig. 20. If further instructions are necessary it is possible that they can be found in storage battery manuals or in texts on the repair of storage batteries.

QUESTIONS ON CHAPTER III

1. What is meant by corroded battery terminals?
2. What may happen if corrosion has taken effect?
3. Explain in detail how corrosion can be removed and also how to protect against it.
4. What three fundamental things must be considered when contemplating charging a storage battery?
5. What is the difference between direct current and alternating current?
6. Explain how it is possible to tell whether current is direct or alternating.
7. What arrangements can be made for charging from a 110-volt direct current source?
8. Make a diagram showing a suitable arrangement for charging making use of a bank of lamps for resistance.
9. How fast should a battery be charged? That is, what should be the charging rate or the number of amperes?
10. How should a battery be connected to a direct current source?

11. Explain why the direction of current when charging must be opposite to that in which the current flows out of the battery.
12. Explain how the direction of current can be determined, or in other words, which is the positive and which is the negative.
13. Make a sketch showing how a voltmeter should be connected.
14. Make a sketch showing how an ammeter should be connected.
15. How is it possible to charge a storage battery when an alternating current source only is available?
16. If more than one battery is to be charged at a time, how may they be connected?
17. Of what does the electrolyte in a lead storage battery consist?
18. What precautions should be taken when mixing the solution?
19. What are some of the operations involved in storage battery repair?
20. Explain how battery connectors may be removed.
21. Explain how cells may be unsealed.
22. How can elements be removed from cells?
23. How may jars be removed from cases?
24. What can you say relative to assembling batteries?

CHAPTER IV

ELECTRICAL APPLICATIONS IN AUTOMOBILES

43. Applications Involved.—So far in our discussions we have taken up in a more or less general way the fundamentals of electricity; and, somewhat in detail, what might be called the heart of the electrical system, the storage battery. Let us consider now more in detail what is really accomplished by the electrical system and what is required for these accomplishments. Fig. 21 indicates this diagrammatically. Referring to this, we see that the general plan is as follows:

When circuits are properly provided, and the equipment is in good working condition, the manipulating of switch *A* results in the lighting of the lamps; the closing of switch *B* causes the starting motor to turn the engine; the manipulating of switch *C* turns on the ignition; and the automatic switch *D* makes suitable connections for using the generator current when the engine turns it at a suitable speed.

It is evident that the complete system involves:

1. Lamps and lighting.
2. Ignition equipment.
3. Motor equipment.
4. Generator equipment.

Any knowledge of these will, obviously, be of value; and it is the purpose in the following discussions to bring out points of importance relative to them.

44. Lamps and Lighting.—Lighting by electricity is brought about by causing an electrical current to flow

thru the filament inside of lamp bulbs. The problems involved in their use are largely those of proper selection and proper provision of circuits and connections since they will operate satisfactorily on pressures which will cause sufficient current to flow thru them. The object in every case is to have sufficient current flow thru them and to have suitable arrangement for controlling them.

In the selection of lamps for any given case the type of wiring must be considered as well as the size and candle power of the lamps. Typical lamp bulbs are shown in Fig. 22. In some systems single contact bulbs are used while in others double contact bulbs are required. This will be understood when the one-wire and two-wire systems are considered and when the methods of dimming lights have been discussed.

45. Ignition Equipment.—The purpose of the ignition equipment is to cause a spark in each cylinder at just the right time to ignite the gas in the cylinder. These sparks are usually provided by suitable application of electricity to spark plugs which are screwed into the engine cylinders. A sketch of a typical spark plug is shown in Fig. 23. The two parts of the electric circuit in the plug are provided by the metal part of the plug that screws into the cylinder and a piece of metal, heavily insulated from the outer part, which extends almost to the lower terminal. The spark is caused to “jump” from one point to the other, and in doing so it ignites the gas.

The resistance of the air space between the two points is very high and the voltage required to cause the spark is many times greater than that furnished

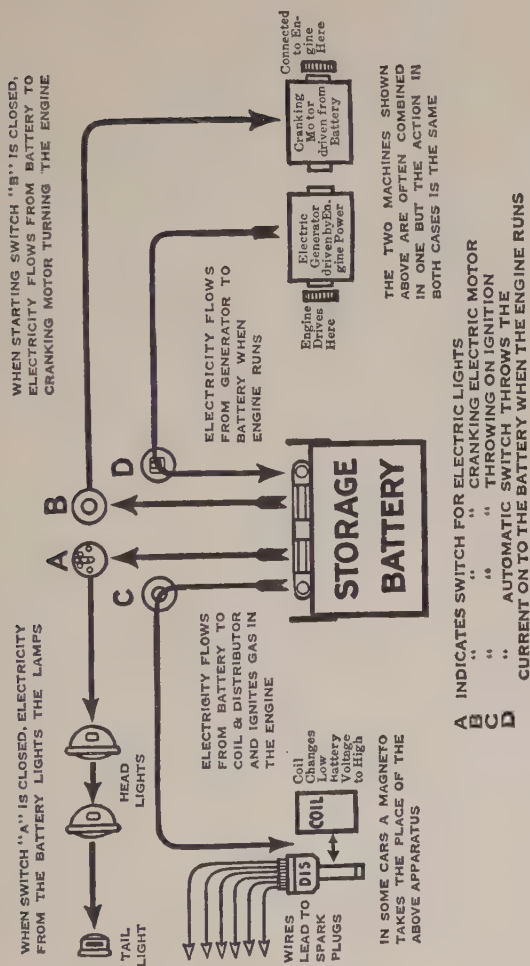


Fig. 21. A diagram illustrating the electrical system in an automobile.

by the battery or generator. This necessitates the use of something that will produce this very high voltage. It has been found that by means of an induction coil a battery or generator voltage can be increased many times; and also that this high voltage can be produced

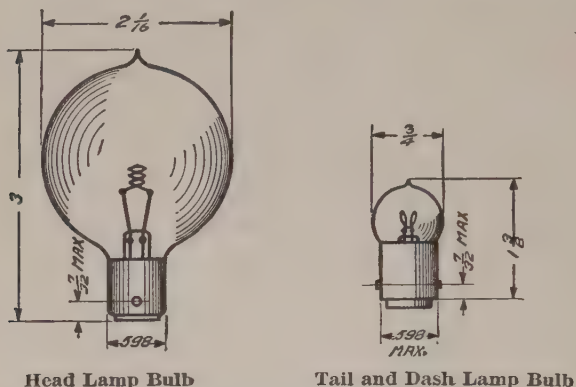


FIG. 22. Typical electric lamps for automobiles.

by a high-tension, or high-voltage, magneto. Thus we see the value of an understanding of induction coils and magnetos.

Not only must the sparks be produced in the cylinders but they must be produced at the right instant. This necessitates the use of some kind of a timing device.

The coil and the magneto depend for their operation upon an electrical phenomenon known as induction and can best be understood after a discussion of this which follows.

46. Motor Equipment.—The purpose of the starting motor is to turn over the engine when starting. This,

we know, requires a large current. (See Sec. 7.) Therefore, good connections and contacts must be provided to the storage battery, to the starting switch, and to the motor. The motor itself depends for its operation upon magnetism and magnetic lines of force which will be discussed later, but the troubles in its circuit may be readily detected and remedied without this knowledge. Any bare spots on the cable should be covered with friction tape, and the starter switch should be cleaned if found oily or dirty. This can be accomplished by washing it with ammonia water, gasoline, or kerosene. A sketch of a starting motor is shown in Fig. 24.

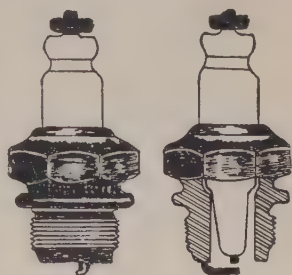


FIG. 23. Sketches of a spark plug.

47. Generator Equipment.—The function of the generator is to furnish current for several purposes including charging the storage battery. The operation

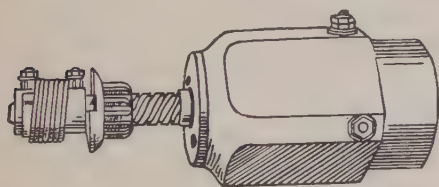


FIG. 24. A sketch of a starting motor.

of the generator, also, depends upon magnetism and induction and can best be understood after a study of these. However, it may be taken for granted that this part of the electrical system will not function properly, even tho it may be in good working order, unless all connections and all parts

of its conducting circuit are good. These may be checked over and repaired without a definite knowledge of the working of the generator itself. The generator is simply a source of electrical pressure.

48. The Automatic Switch.—Later in our study we shall find that the voltage of a generator depends upon the speed at which its armature is being revolved. When it is stationary, no voltage will be impressed upon its terminals. It is evident, then, that if the generator were left connected to the storage battery at all times, the battery would force current thru the generator if the latter were not moving sufficiently fast. This would run the battery down and injure the generator. The automatic switch opens the circuit between the generator and storage battery if the voltage of the generator is not greater than that of the battery.

QUESTIONS ON CHAPTER IV

1. Give a brief description of the applications involved in a typical electrical system in an automobile.
2. Into what four general parts may the electrical system be divided?
3. How is lighting brought about by the use of electricity?
4. What must be taken into consideration when selecting lamps?
5. What is the purpose of the ignition equipment?
6. How are the two parts of the electric circuit provided in a spark plug?
7. How does the voltage required to cause a spark over the points of a spark plug compare with that of the storage battery?
8. How is it possible to produce this voltage?
9. Why is a timing device necessary?
10. What is the purpose of the starting motor equipment?

11. How does the current required for operating the starting motor compare with that required by other parts of the system?
12. What simple troubles in the starting motor circuit may be readily detected and remedied?
13. What is the function of the generator?
14. Why is the automatic switch necessary?

CHAPTER V

ELECTRICAL CIRCUITS

49. Lighting Circuits.—In the automobile, several different lighting circuits are involved. In every case we find electric head lights and a cowl and tail light,

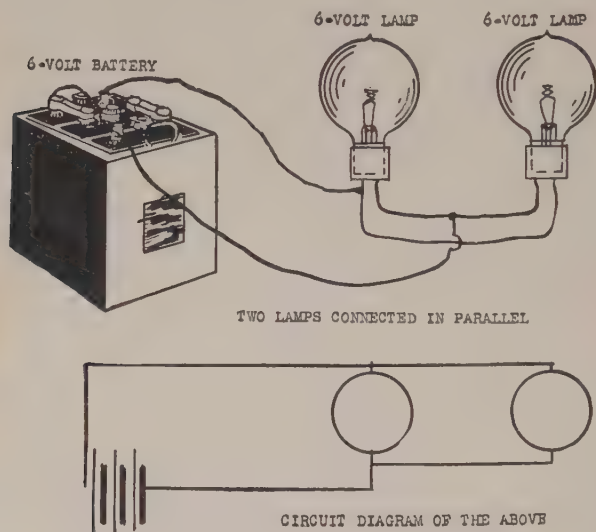


FIG. 25. A sketch and circuit diagram of two lamps connected in parallel.

and in many cases others including dome lights, stop lights, spot lights, etc. An understanding of the proper provision and use of these requires a study of some of the basic lighting arrangements.

50. Lamps Connected in Parallel.—In Fig. 25 is a sketch of two lamps connected in parallel and below it

is shown what is commonly called a circuit diagram. In such a diagram, certain symbols are used for lamps and batteries, and wires are represented by lines. By connecting two lamps in parallel, we mean connecting both terminals of one lamp to both terminals of the other. The connections from the source of pressure may be made to either lamp or to the wires connecting them. It will be seen that with this arrangement either lamp can be removed without affecting the other and that the full voltage of the source is impressed upon each lamp. In other words, if the battery gives a pressure of 6 volts, the lamps should be 6-volt or perhaps a little higher. When lamps are connected this way, two parallel paths are provided for the current coming from the battery, the resistance is one-half that of one lamp, if the filaments are the same, and the lamps draw twice as much current as does one. (See Sec. 8.)

51. Lamps Connected in Series.—Fig. 26 is a circuit diagram of two lamps connected in series. By connecting two lamps in series, we mean connecting one terminal of one to one terminal of the next and the feed wires to the remaining two terminals. With such an arrangement the current must pass thru one lamp before it can get to the other, or if one lamp goes out the other does likewise. This arrangement is often used in connecting the cowl, or dash, lamp and the tail lamp. Then if the cowl light goes out it indicates that the tail light is out also.

With this arrangement the resistance against the flow of current is that afforded by both lamps acting together. Thus the voltage required to operate two

6-volt lamps connected in this manner would be 12, but the 6-volt pressure will be sufficient if 3-volt lamps are used. In any case, the voltage of the lamps should be one-half the voltage of the battery or other source of pressure.

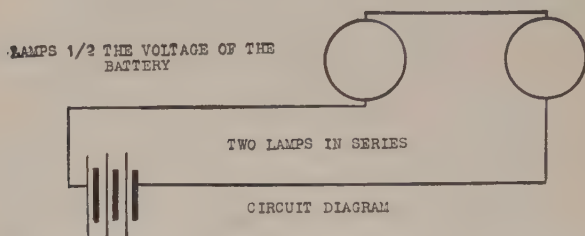


FIG. 26. A diagram of two lamps connected in series.

52. A "One-Wire" System.—One of the important requirements for any electrical circuit, as pointed out in Chapter I, is that of having a complete circuit of conducting material. A so-called one-wire system is no exception to this. When this system is used, wires lead from one side of the source to each piece of electrical apparatus to be operated and the other sides of the circuits are provided by the frame of the automobile. This is not unlike having several oiling tubes carrying oil to various bearings with a common return thru the crankcase.

When a one-wire system is used, one side of the battery is connected to the frame, or grounded as it is called, and then one side of each electrical device is grounded either by a short wire or directly thru its frame or support. Such an arrangement is shown in Fig. 27.

53. How Lights Can Be Dimmed.—Because of the blinding effect of bright lights it is often necessary to dim them. This can readily be accomplished. The lighting of a lamp is dependent upon the rate at which current is forced thru its filament. This rate we know

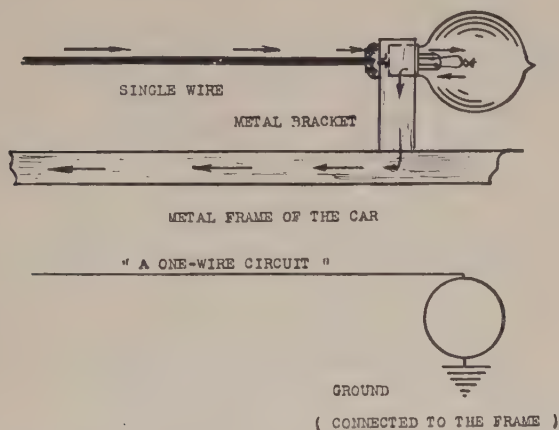


FIG. 27. A sketch and wiring circuit diagram of a one-wire arrangement.

(Sec. 7 and 8) depends upon the voltage impressed upon the lamp and the resistance in the circuit. If the lamp does not have sufficient current flowing thru its filament it will give a dim light. Thus the dimming may be brought about by the use of a piece of high-resistance material connected in the circuit as indicated in Fig. 28. This dimming may be brought about by reducing the voltage over the lamp in any way or by providing two filaments in the bulb or by using two sets of lamps, one of high candle power and one of low candle power.

54. A Typical Lighting Circuit Diagram.—In Fig. 29 is shown the lighting portion of a typical circuit diagram. The two head lamps are connected in parallel. The dash lamp and tail lamp are connected in series. The ammeter, which indicates the current passing out of the battery, is connected in the main

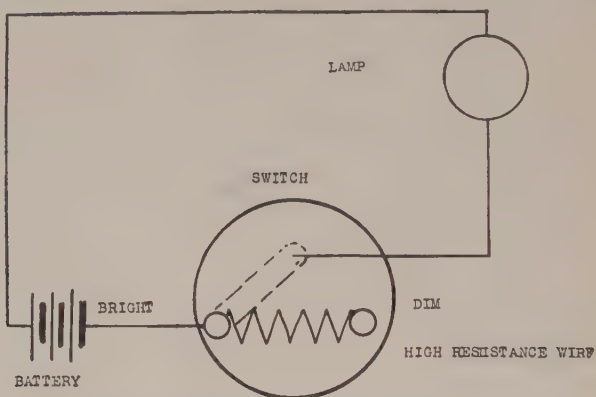


FIG. 28. Illustrating how lamps may be dimmed with a high-resistance coil.

circuit leading from the battery to the switch. In both of the lighting circuits are placed fuses which will “blow,” or melt, if two wires accidentally come in electrical contact, or “short circuit” the battery which would cause it to “run down” rapidly and perhaps cause the wires to become exceedingly hot.

If these circuits are followed, it will be found that the switch as shown is not sufficient, since the current which passes thru the tail lamp and the dash lamp must pass thru the resistance when the switch is in the “bright” position. It would be necessary to pro-

vide some means of making a connection to the wire leading directly to them when the switch is in this position. Complications of this nature make it necessary to have switches which are more or less complicated looking; but the purpose in every case is simply

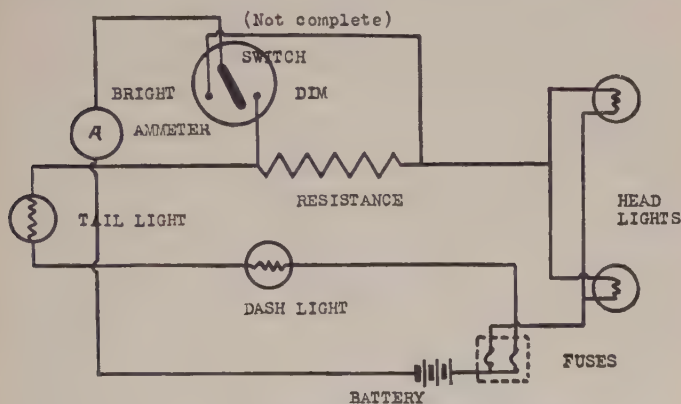


FIG. 29. A battery lighting-circuit diagram.

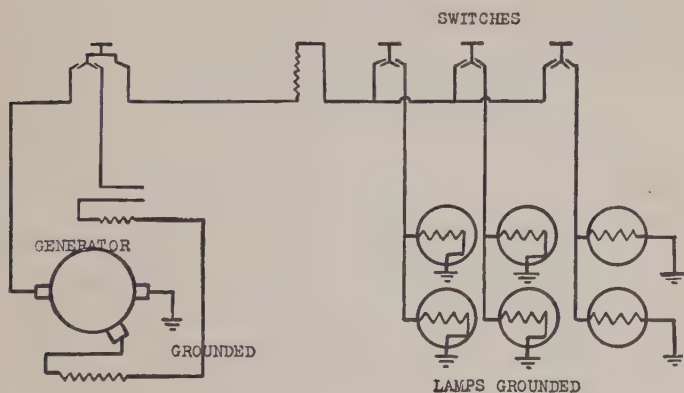


FIG. 30. A generator lighting-circuit diagram (One-wire).

to fulfill the fundamental requirements. In Fig. 30 is represented part of a diagram in which three sets of lamps in groups of two each are supplied with current by a generator. This diagram represents a one-wire system.

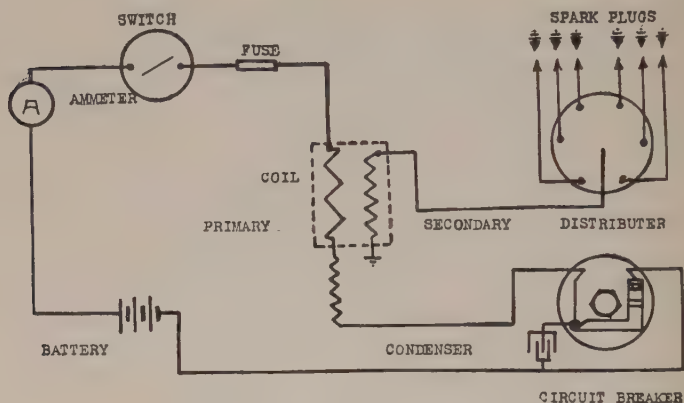


FIG. 31. A battery ignition-circuit diagram.

55. Ignition Circuits.—In Fig. 31 is shown a diagram which provides for battery ignition for a six-cylinder engine. When the switch is closed, current passes thru the ammeter, the fuse, the primary circuit of the coil, a resistance, thru the circuit breaker, or interrupter, and back to the battery. The high voltage for the spark plugs comes from the secondary to the distributor, from the distributor to the spark plugs and thence thru the frame back to the other terminal of the secondary. The purpose of the condenser connected over the circuit breaker will be explained later, as will also the action of the induction coil.

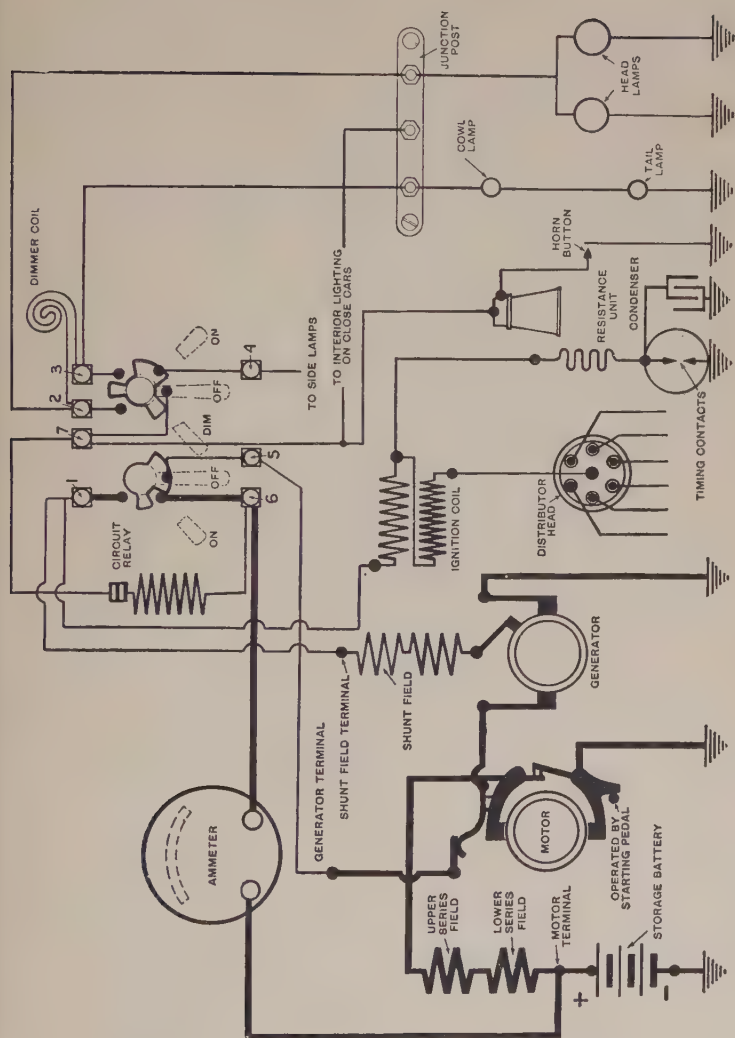


FIG. 32. A complete electric-circuit diagram.

56. Other Circuits.—A complete electrical system comprises a large number of circuits but such a system of circuits is not as complicated as it might appear. A typical circuit diagram is shown in Fig. 32.

In every case, whether it be the horn circuit, the starting motor circuit, lighting circuits, or the complete system, the fundamental principles only are involved.

Assistance is afforded also by wiring diagrams such as the one shown in Fig. 33, which are usually readily available from the manufacturers of the various makes of automobiles. With the knowledge gained in this study, and perhaps some assistance from diagrams, little trouble should be encountered if the fundamentals are kept constantly in mind.

QUESTIONS ON CHAPTER V

1. List as many applications of lighting in the automobile as you can.
2. Make a sketch of two lamps connected in parallel. How should the voltage of the lamps compare with that of the battery?
3. Make a sketch of two lamps connected in series. How should the voltage of these lamps compare with that of the battery?
4. Explain in the cases of parallel and of series connections the effect of removing one lamp.
5. Explain what is meant by a "one-wire" system.
6. What is meant by a "grounded" wire?
7. Give two methods which may be used for dimming lights.
8. What is the purpose of fuses?
9. Follow the circuits in a typical lighting circuit diagram.
10. Follow the circuits in a typical ignition circuit diagram.
11. Interpret a typical electrical circuit or wiring diagram.

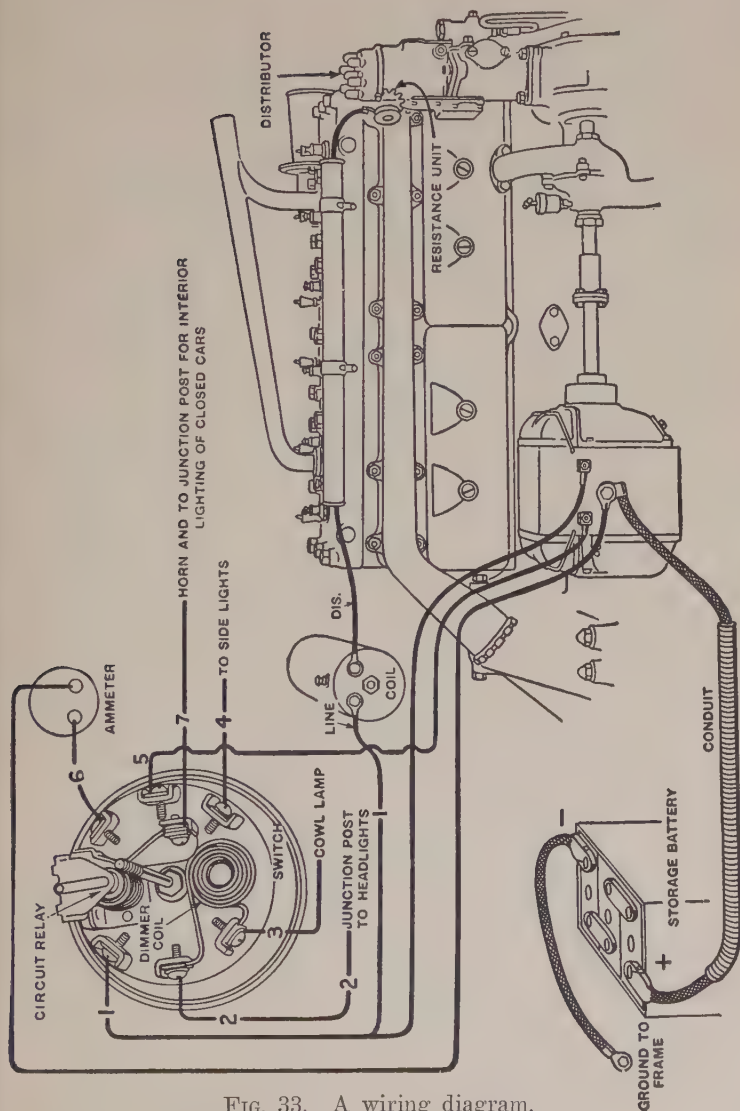


FIG. 33. A wiring diagram.

CHAPTER VI

MAGNETS, MAGNETISM, AND MOTORS

57. Why Study Magnetism?—In our previous discussions it has been necessary to omit many things relative to the various devices, especially motors, magnetos, and generators, because we have not yet taken up the fundamental principles upon which they operate. It is difficult to discuss them intelligently, or to know just what to expect of them until we have a knowledge of these principles. If we get these fundamentals clearly in mind, it will be easy to understand how these devices function and also what troubles to look for in case they do not function properly. It is the phenomena of magnetism upon which these devices, or machines, depend for their operation.

58. What is Magnetism?—Up to the present time, nobody has been able to explain just what magnetism is. The modern idea is to imagine it as lines or streams of force. This is quite imaginary, but it is a rational theory and it gives a very good basis for practical work. The modern method of dealing with magnetism is to consider that it flows or passes thru a magnetic circuit similarly to the flow of electricity thru an electrical circuit. It must be understood that electricity and magnetism are entirely different in many respects but that they are closely related. Iron and steel are the best conductors of magnetic lines of force, practically all other metals and materials being unaffected by them. Thus, copper, brass, aluminum and other metals which will conduct electricity, permit mag-

netism to pass thru them but do not assist in transmitting it. Likewise, paper, cloth and the like, which are used as non-conductors of electricity, are unaffected by magnetism, and they do not affect its flow. That is, the magnetism will pass right thru them.

59. Common Permanent Magnets.—Most of the readers have seen permanent magnets of one kind or another. The small horseshoe and the bar magnet are quite common. Magnets of this kind are made of a good grade of hard steel. The pieces of steel have been magnetized by causing lines of magnetism to pass thru them. Magnets of this kind are capable of picking up or attracting pieces of iron or steel such as pins, needles, tacks, and the like. If we make a brief study of the characteristics of these magnets, we find that several laws relative to them always hold true.

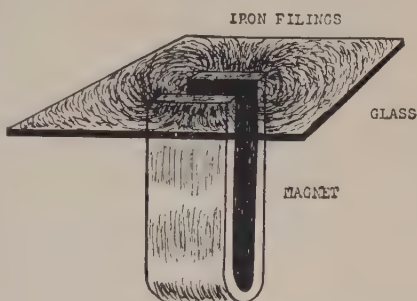


FIG. 34. A sketch showing how magnetic lines of force can be shown.

60. Characteristics of Magnets.—If a piece of glass or paper is placed over a magnet and small particles of iron are sprinkled on the glass, we find that these particles arrange themselves in definite lines as indicated in Fig. 34. The lines indicated by these particles are what are commonly known as lines of force, and the space in which they exist is commonly known as a magnetic field. In our later discussion of various de-

vices we shall see that these lines of force, or the magnetic field, are very important.

The parts of the magnet, usually the ends, about which these lines of force are most numerous, or where the magnetic field is the "strongest," are called the poles of the magnet.

Further experimenting with magnets shows that not

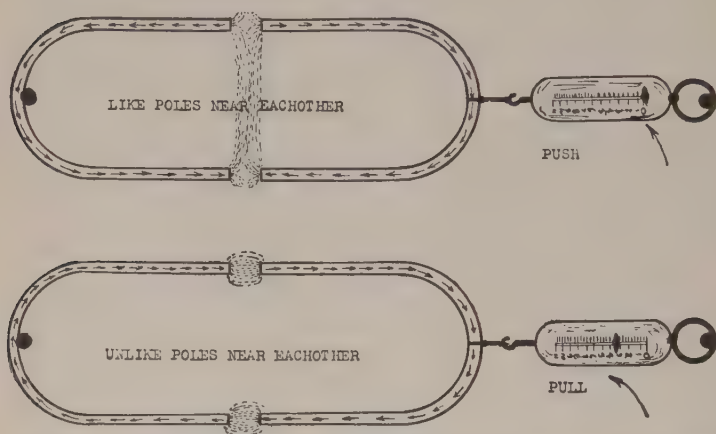


FIG. 35. Illustrating the attracting of unlike poles and the repelling of like poles.

only do these lines of force exist about the poles of the magnet, but also that they have a definite direction, coming out of one pole and going into the other. This is indicated by the fact that two magnets placed near each other may attract, or pull each other, or repel, or push, each other, depending upon the direction of the lines of force in the poles brought near each other. This is illustrated in Fig. 35. The poles of a magnet in order to distinguish them have been named

north pole and south pole because one will point in a north direction and the other in a south direction if the magnet is left free to revolve.

The foregoing tests, and others, lead us to the following definite conclusions:

1. Magnets have a magnetic field existing in the space about their poles.
2. This magnetic field is made up of lines of force which flow readily thru iron or steel.

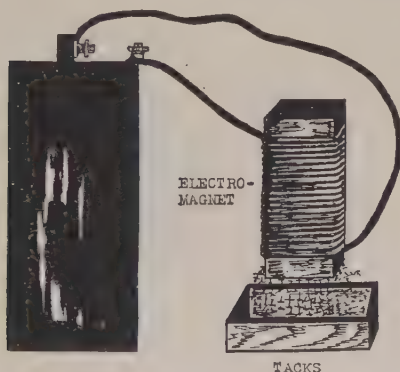


FIG. 36. A sketch of an electro-magnet.

3. The lines of force in this magnetic field have a definite direction.

61. Electro-Magnets.—Experience has shown that if covered wire is wound upon a piece of iron such as a nail or bolt, and an electric current passed thru the winding, the piece of iron becomes a magnet, Fig. 36. This magnet has the same characteristics as does the permanent magnet. It has a magnetic field about its poles also, the strength depending upon the number

of turns of wire in the coil and the strength of the current or the number of amperes. The direction of the lines of force in the case of such a magnet depends upon the direction in which the current is flowing thru the coil. This can easily be shown. If, as in Fig. 37, a permanent magnet is suspended over the poles of the electro-magnet, it will take a definite position, one

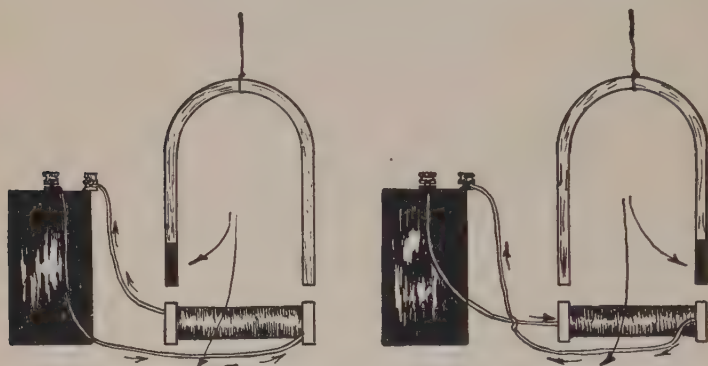


FIG. 37. Illustrating that the polarity of an electro-magnet depends upon the direction of the current thru its winding.

of its poles being attracted by one of the poles of the electro-magnet. If the connections to the battery are reversed, so the current will flow thru the coil in the opposite direction, the permanent magnet will turn half-way around.

It has been proved and demonstrated that the polarity of an electro-magnet can be determined in the following manner: Grasp the coil with the right hand in such a way that the fingers encircle it in the direction of the current thru its turns and the thumb will point toward the north pole of the magnet. Therefore,

since we know, or can determine, the direction of a current, we can readily determine the polarity of a magnet.

If, with the arrangement shown in Fig. 37, the battery connections to the electro-magnet coil, or the direction of the current thru it, can be reversed at just the

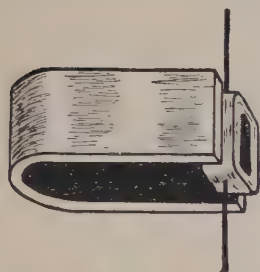


FIG. 38. A coil of wire between the poles of a magnet will move if current is sent thru it.

right instant, the permanent magnet will make a complete revolution; and if this process can be continued the rotation of the magnet will be continuous, provided the reversals in the direction of the current can be brought about at the proper instants. This is, of course, quite difficult to do manually.

62. A Simple Motor.—It should be understood that this action between magnets is mutual. That is, the permanent magnet may move and the electro-magnet remain stationary, or the electro-magnet move and the permanent magnet remain stationary if suitable means is provided for the connections.

Now, if an iron core for an electro-magnet be placed on a shaft, the winding put on, and the ends of the winding connected to two half-round cylindrical pieces, such as the end of a cartridge fuse cut in two, which are attached to the shaft but insulated from it and from each other, a simple motor may be made. This arrangement, if held or supported over the poles of another magnet, will revolve continuously when an

electrical current is passed thru its winding. The direction of rotation may be reversed by simply reversing the direction of the current thru the coil.

63. Principle of the Electric Motor.—From the foregoing it is evident that rotation can be produced if two magnetic fields are brought near each other or in com-

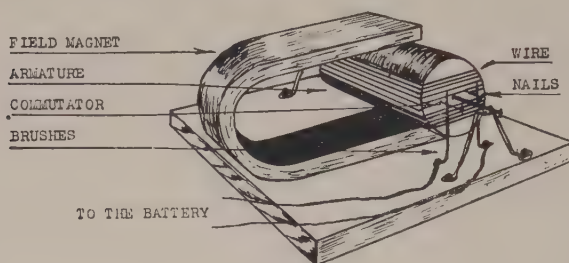


FIG. 39. A simple electric motor.

bination with each other in the proper manner. Let us consider this further.

The fact, that when insulated wire is wound on an iron core and a current is sent thru it a magnet is produced, seems to indicate that lines of force encircle the coils of wire. It is easy to prove that this is a fact. Particles of iron will cling to a wire carrying a large current or they will indicate lines of force if the wire is passed thru a paper and the filings or small particles are sprinkled on it.

A single U-shaped wire, or an open coil of wire such as shown in Fig. 38, will make a portion of a revolution when an electrical current is passed thru it, if it is placed between the poles of a magnet, or in a magnetic field. Now if some arrangement is made for reversing the direction of the current thru the coil at

the proper instant, it can be made to revolve. The direction of rotation depends upon the direction of the current thru the coil and the direction of the lines of force in the magnet. Such an arrangement might be provided in an experimental way as shown in Fig. 39.

In this simple arrangement, the permanent magnet provides the magnetic field; the coil of wire on the cylinder, commonly known as the armature, rotates; and the two nails to which the ends of the coil are connected taking place of what is commonly known as the commutator, provide a means of reversing the direction of the current at the proper moment to produce continuous rotation. The wires leading from the battery or other source are connected to wires or pieces of metal which come in contact with the "commutator bars." These pieces are what are commonly known as brushes.

Reversal of the direction of rotation of the armature may be brought about by reversing the connections to the battery, which reverses the direction of the current thru the coil; or by turning the magnet over, which reverses the direction of the lines of force in the field.

64. The Electric Motor.—The practical electric motor is simply a working application of the preceding principles. Consider the sketch of the electric horn motor in Fig. 40. This, we see, consists of four fundamental parts: viz., the field, the armature, the commutator on the armature shaft, and the brushes. Likewise the starting motor, or any other direct current motor, consists of these essential parts.

65. The Field.—The purpose of the field is, just as indicated by its name, to produce and maintain a magnetic field. This field in our simple case, Fig. 39, was provided by a permanent magnet. Since the same re-

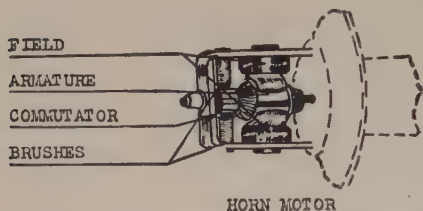
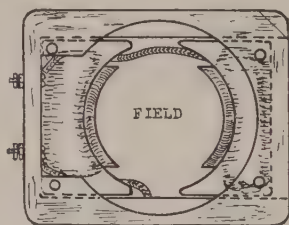


FIG. 40. A sketch of a horn motor showing its parts.

sulting field can be produced by an electro-magnet which can be furnished with electrical current, it is often more logical to furnish the field, or magnetic lines of force, in this way. The field in the case of the horn motor, or the starting motor shown in Fig. 41, is simply provided by a conveniently arranged electro-magnet with two coils instead of one.

If this field winding were examined carefully it would be found that the coils are arranged so that the current will flow thru one in a direction opposite to that in the other. In fact, in any field production, the current is reversed



SYMBOL



FIG. 41. A motor field and the symbol for representing it.

in every other coil. It is not difficult to see why this is necessary if we consider the sketch in Fig. 42. Even tho the winding on a straight magnet be con-

tinuous, as thread is wound on a spool, the directions become opposite if the magnet is bent into a U-shape. Then, too, we have found that the lines of force come out of one pole of a magnet and go into the other, and that the poles of the magnet depend upon the direction of the current thru the winding. It is evident, then, that to produce a magnetic field when the core is other than in the shape of a bar, the current must be passed thru the one coil

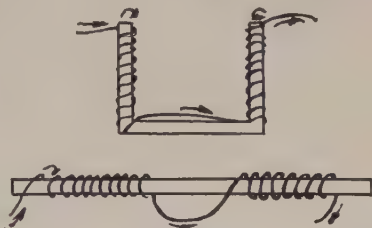
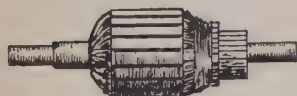


FIG. 42. Illustrating why the current should run in opposite directions thru the coils of a U-shaped magnet.

in a direction which is reverse of that thru the other. This may be accomplished in any possible way. The connections to the coil may be reversed; or if the coil is removable, turning it over will accomplish the desired result.

66. The Armature.—The practical armature consists



ARMATURE



SYMBOL

FIG. 43. A sketch of an armature, and the symbol for representing it.

simply of a series of coils of covered wire wound in the proper manner in slots in an iron core. See Fig 43. The ends of these coils are brought out and connected to the proper bars of the commutator. The manner in which these coils are connected to the bars depends upon the number of poles in the field, or, in

other words, the number of magnetic fields provided; and also upon the position of the brushes. Any armature winding is simply a modification of the single coil arrangement. In fact, a small armature wound for a two-pole field will revolve if supported in the field of a permanent magnet and current sent thru it as in the simple motor.

67. The Commutator.—The commutator consists, simply, of a series of copper bars insulated from each other and from the armature shaft. Their purpose is to provide a means of making a connection to the armature coils, even tho they are revolving, and, at the same time, to reverse the direction of the current thru the coils at the proper moment.

68. The Brushes.—The purpose of the brushes is to provide a means of carrying the current to the commutator bars from which it goes to the armature coils. These brushes rub on the bars of the commutator and are, therefore, made of a material which will not wear the commutator excessively but will still make good contact. They may be made of carbon and held in contact with the commutator with springs.

69. Internal Motor Connections.—Knowing the essential parts and their purpose, there remains the question of connecting these parts. The operation of the motor depends, primarily, upon the passing of an electrical current thru the field coils to produce a magnetic field; and thru the armature coils to produce lines of force around them. It is evident that this may be accomplished by connecting the armature and field coils in series or by connecting them in parallel, or shunt. These methods of connecting are shown in Fig.

44. If the field coils and armature are connected in series, the machine is said to be a series connected machine; if they are connected in parallel, or shunt, it is said to be shunt connected. The operating characteristics of the motor are governed very largely by the method of connection. This will be discussed later.

70. Maintenance and Repair of Motors.—The parts, the maintenance and the repair of motors are very much similar to those of generators. In fact, some

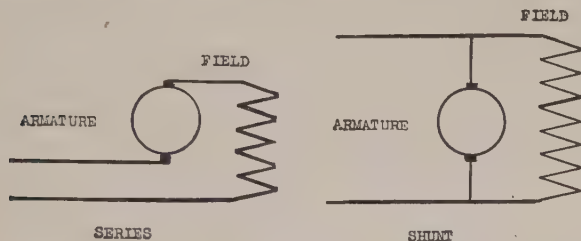


FIG. 44. Diagrams of series and shunt-connected motors.

machines are either motors or generators. Consequently we shall take up the maintenance and repair of both after we have become familiar with the characteristics of the latter.

QUESTIONS ON CHAPTER VI

1. Why is a knowledge of magnetism important?
2. Tell what you can about the nature of magnetism.
3. What materials are best conductors of magnetism?
4. Make a list of materials that do not affect magnetism.
5. Describe a common permanent magnet.
6. Of what kind of material must a good magnet be made?
7. Explain how it is possible to make a study of magnetic lines of force by the use of iron filings.
8. What is a magnetic field?

9. What are the poles of a magnet?
10. What can you say about the direction of lines of force?
11. What three important conclusions can be drawn relative to magnets and magnetic fields?
12. What is an electro-magnet?
13. Upon what does the polarity of an electro-magnet depend?
14. Explain how motion can be produced by means of magnets.
15. How can it be shown that lines of force encircle a wire when a current is passing thru it?
16. Explain how a simple electric motor can be made.
17. What are the essential parts of an electric motor?
18. What is the purpose of the field?
19. Explain why the coils on a two-pole field are wound in opposite directions or the current is reversed thru them.
20. What is the purpose of the armature?
21. Upon what does the manner in which the coils on the armature are connected to the commutator depend?
22. Of what does the commutator consist?
23. What is the purpose of the commutator?
24. Why are brushes necessary?
25. What two methods of connecting the field and the armature are used?
26. Make a diagram of a series connected motor.
27. Make a diagram of a shunt connected motor.

CHAPTER VII

MAGNETOS, GENERATORS, AND COILS

71. Magnetos.—In Chapter II it has been stated that magnetos provide sources of electrical pressure and in Chapter IV their use has been mentioned. In short, magnetos are machines which when operated by some mechanical means will produce an electrical pressure suitable for certain purposes such as ignition, and in some cases lighting.

72. Generators.—Generators, we have learned, are machines which are suitable for furnishing electrical pressures for such purposes as lighting, ignition, and charging storage batteries. The magneto is also a generator in one sense of the word, but it has been given the name “magneto” because it has permanent magnets. The machines commonly known as generators have electro-magnets, or electro-magnetic fields. Generators, too, must be operated by some mechanical means.

73. Fundamental Characteristics of Simple Magnetos.—Let us consider, more or less in detail, characteristic constructions of these electrical machines and see how they apply simple principles of electricity and magnetism,

Magnetos are made in various forms there being almost no limit to their number. However, every one will be found to consist, essentially, of permanent magnets and a coil, or coils, of wire with some moving part. This tends to indicate that *magnets, coils of wire, and motion* are fundamental essentials in magnetos. It is

logical to assume, therefore, that study and experiment in connection with the action between permanent magnets and coils of wire when either is in motion should bring out something of importance in relation to their application in magnetos. This is borne out in practice; and by taking into consideration certain laws of physics, and other valuable information of a somewhat theoretical nature, one can readily show by means of concrete things that certain phenomena always take place; and, even tho we may not be absolutely certain as to the cause, we may draw certain definite conclusions as to results.

74. Fundamental Happenings.—If the ends of a coil of covered wire be connected to a very sensitive meter as indicated in Fig. 45 and a permanent magnet be used in connection with these as indicated, it will be found that the pointer of the meter moves in one direction as the magnet is being thrust into the coil but in the opposite direction as the magnet is being brought out of the coil. The reading immediately drops to zero whenever the motion is stopped regardless of the position. If the magnet be turned over, the meter readings will be reversed. That is, when the magnet is being thrust into the coil the pointer will swing in the same direction as it did previously when it was being brought out. It will be found also that the reading on the meter, or the swing of the pointer, will vary with the speed at which the magnet is moved. That is, if the magnet be thrust in suddenly, a comparatively large reading will result, but if it be moved slowly, the reading may be so low as to be practically negligible.

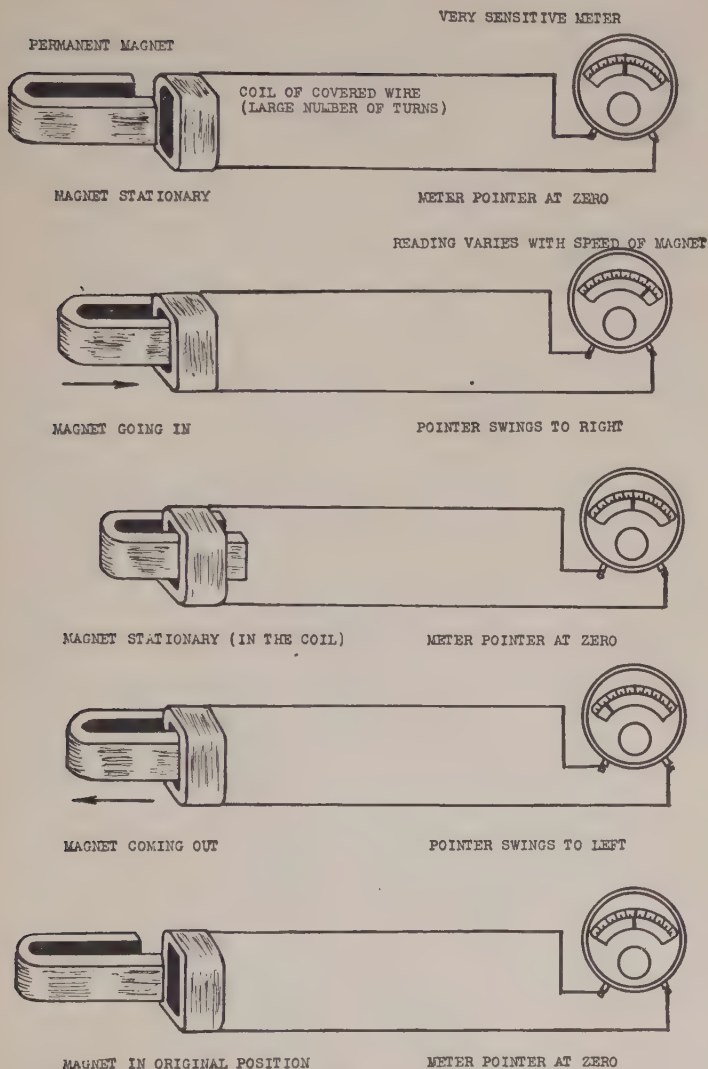


FIG. 45. Illustrating how an electrical pressure is set up in a coil by the use of a permanent magnet.

For this to take place satisfactorily in the manner described above, the coil must consist of a large number of turns of covered wire. In fact, the reading on the meter depends upon the number of turns of wire and the strength of the magnet. The coil may be held together with tape covering its entire surface without affecting the result. The meter must be very sensitive, (a millivoltmeter or a galvanometer.)

75. The Analysis of These Happenings.—Knowing that the things mentioned above always take place and have actually been accomplished time after time, let us analyze this and try to determine why they happen.

First, we know that the motion of the pointer on the meter indicates the flow of an electric current thru the meter coil, and that the magnitude of the reading indicates the magnitude of the current passing thru the coil. These things being known, it is evident that something brought about by the moving of the magnet into and out of the coil has caused an electric current to flow thru the coil and the meter. It is evident also that the direction of the current reversed as the direction of motion of the magnet was reversed. The turning over of the magnet brought about a reversal in the direction of the current also. Therefore, not only the direction of the motion but something else as well, affected the direction of flow of current thru the coil.

76. Lines of Force Are Involved.—Every magnet is known to have poles surrounded by magnetic lines of force as can be easily shown by sprinkling iron filings on a piece of paper or glass placed over the magnet as indicated in Fig. 34. It has been shown also that

these lines of force have a definite direction apparently coming out of the north pole and going into the south pole. This being the case, it is evident that the current set up in the coil, and indicated by the meter, must have been caused by the wires cutting the lines of force existing between the poles of the magnet. The fact that the turning over of the magnet produced a reversal in the direction of the current shows that the direction of the lines of force must influence the direction of the current.

77. Cutting Lines of Force Produces Voltage.—We may logically conclude that the cutting of lines of force by the wire sets up a voltage, or electrical pressure in the wires which will cause a current to flow if a closed circuit is provided. This conclusion is brought out more emphatically by additional experimenting which shows that the results may be obtained equally well by moving the coil and having the magnet stationary or by using a field produced by an electro-magnet instead of a permanent magnet.

78. Logical Assumptions.—From the foregoing observation and reasoning, it is logical to assume:

1. When a conductor, or coil of wire, interferes with lines of force, or when lines of force are cut by a conductor, an electrical pressure is set up in the conductor, or the coil.
2. The greater the number of turns in a coil, the greater the interference will be, and hence greater voltage will result.
3. The magnitude of the voltage depends upon the speed at which the lines of force are cut.
4. The direction of the pressure depends (1) upon

the direction of the lines of force and (2) upon the direction of the motion.

79. Applications of These Principles.—With these points in mind, let us now consider some of the practical applications in some of the more common machines and devices. Perhaps the most striking, and almost di-

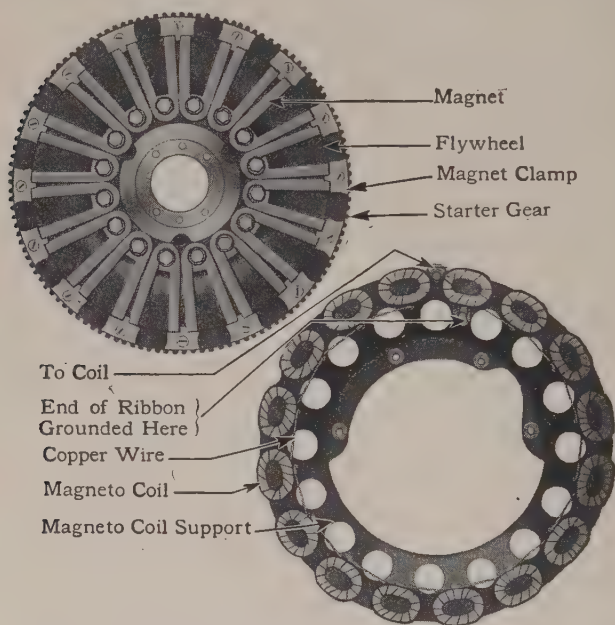


FIG. 46. The Ford magneto.

rect application of this action is found in the Ford magneto.

80. The Ford Magneto.—The Ford magneto, with whose characteristics many people are familiar, consists, essentially, of a series of coils on an iron, or steel frame or plate which remains stationary; and

a series of permanent magnets attached to the fly-wheel. See Fig. 46. One end of the coil-windings is attached to the frame, or grounded, and the other is attached to a piece of metal insulated from the frame, from which the circuits are made to the various parts of the system and back thru the frame of the machine. It is apparent that this is almost a direct application of the principles brought out in the previous discussion. The series of magnetic fields produced by the permanent magnets when revolving with the flywheel are cut by the coils of ribbon and a voltage is set up in the coils which is used for the various effects with which everyone is familiar.

81. Other Magnetos.—All other magnetos bring about the direct cutting of lines of force by coils of wire on a revolving armature or by bringing about changes in the lines of force encircling coils of wire either of which will cause a voltage to be set up in the coils.

The armature type of magneto consists, essentially, of the permanent magnets which provide the field and coils of wire wound on an armature which can be revolved in this field and thereby bring about the cutting of the lines of force by the coils and the producing of a voltage in them. The current which may be delivered by these coils can be carried from the coils in any desirable way. In many cases one end is connected to the armature and the other end to a ring insulated from the armature shaft. Current may then be led from this ring to the place where it is to be used and back thru the frame of the magneto. Fig. 47, showing a series of sketches indicating the manner in

which the wires in the coil on the armature cut thru the lines of force, will perhaps make clear how such a magneto operates.

Not only is an electromotive force, or voltage, set up when a magnet, or series of magnets, is moved near a coil of wire so that the lines of force are cut and also when a coil of wire is moved or revolved so it cuts

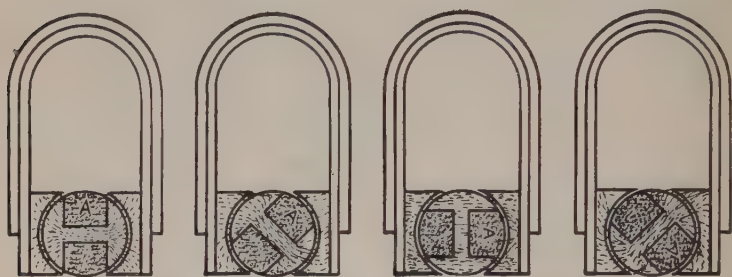
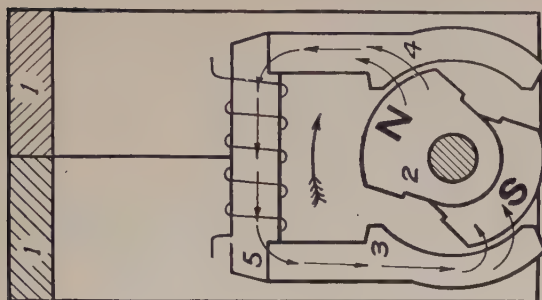


FIG. 47. Sketches showing the action in an armature type of magneto.

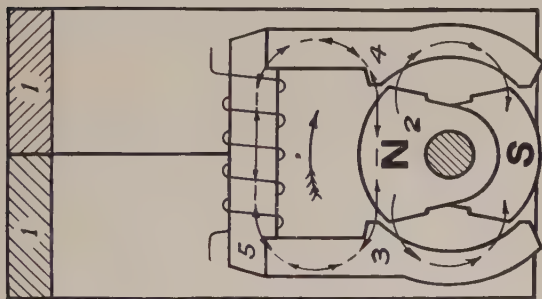
lines of force, but a voltage is set up in a coil also when the lines of force, or magnetic flux as it is often called, which are threading thru or encircling the coil are changed. This changing of lines of force probably brings about cutting of the lines of force by the wires of the coil but whether or not this is true the resulting voltage is known to be produced.

In an experimental way this can be shown with the coil of wire and the meter as previously described. If two magnets, one from each side, are passed thru the center of the coil and placed together so there is attraction, or a large number of lines of force passing thru the coil, and then suddenly pulled apart, a voltage will be indicated on the meter.



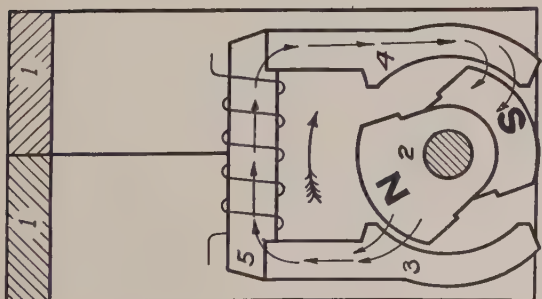
5. LAMINATED CORE OF H.T. WINDING

The flux flows in reverse direction thru core 5. Wing N has moved over to 4 and the direction of the flow of flux is reversed, now flowing from 4 thru 5 to 3.



3 and 4. LAMINATED POLE PIECES

The rotating wings occupy a midway position. Pole pieces 3 and 4 are magnetically short-circuited as it were; thereby scavenging stray lines of flux out of the core 5.



1. MAGNETS

2. ROTOR WINGS

The flux flows in one direction thru core 5. When wing N is opposite 3, flux flows to 3 and thru 5 to 4, back to wing S of opposite polarity.

Fig. 48. Diagrams showing principle of operation of Dixie Magneto.

A practical application of the setting up of an electrical pressure by changing the magnetic lines of force, or flux, in a magneto is found in the "Dixie" manufactured by the Splitdorf Electrical Company. Diagrams showing the principle of operation of this magneto are shown in Fig. 48.

82. Alternating Current is Delivered by Magnetos.—

If we take into consideration the fact that the moving of the magnet thru the coil of wire as in Fig. 45 caused a current to flow first in one direction and then in the other, it can readily be seen that the current caused by a magneto will do this also. This is an alternating current. There is no means of making the magneto furnish a direct current.

83. Generators.—Since the generating of an electrical current, or rather the producing of a voltage which causes an electrical current to flow in a circuit, depends upon the cutting of lines of magnetic force by wires or coils, a little consideration will show that the arrangement and parts fundamentally the same as those of the motor in Fig. 39 and others will produce desired results if the armature is revolved by some outside means. Not only will the setting up of an electrical pressure result but the commutator and brushes will cause connection to the various coils in such a way that the current will always flow in the same direction, or in other words it will be direct current. This is explained by the fact that the coils on the armature are connected to the commutator bars for the purpose of reversing the direction of the current thru them at just the right instant to keep up a continuous motion. Now, reversing the process, turning the armature or run-

ning the machine as a generator, this change in connection to the coils will take place just as they start to cut the lines of force in the opposite direction or just as the current is about to reverse. Thus the current is kept flowing out of one brush and into the other at all times. The generator is essentially the same as a motor and it consists of the same parts in the same relation to each other. The windings on the field poles are furnished with current flowing from the armature. A few lines of force, or a little magnetism, remains in the field. These are sufficient for starting the process under ordinary conditions. If no magnetism whatever is present it is sometimes necessary to send a current thru the field coils until the poles become magnetized.

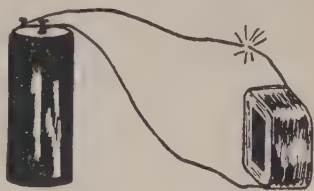


FIG. 49. Illustrating the causing of increased voltage by the use of a coil.

84. Induction.—From the foregoing we see that an electrical pressure, or electromotive force or voltage, is set up when lines of force are cut by a wire or coil. The lines of force may be moved or the wires may be moved. These are not the only methods of causing electrical pressures, however. It is possible to cause an electrical pressure to be set up in a wire or coil without the moving of a magnet or the moving of a coil if the lines of force can be changed.

Let us consider a simple experiment which shows this. In Fig. 49 is shown the result of opening the circuit leading to a large coil. The spark brought about in this way is much larger than can be formed

by making a temporary connection to the terminals of the cell. Everyone is no doubt familiar with the fact that one cannot feel the effect of electrical current if he touches the terminals of a dry cell or storage battery. The voltage is not sufficiently high to cause a

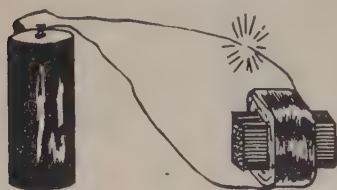


FIG. 50. Illustrating the effect of an iron core in a coil of wire.

noticeable amount of current to pass thru the body. With a suitable coil in the circuit it is easily possible to recognize the effect of suddenly opening the circuit. That is, if the wires are bared at the point where the

spark is shown and held in the hands, a distinct shock will be felt as the circuit is suddenly opened, provided the coil is made of a large number of turns of suitable covered wire. (These shocks are not dangerous.)

Now if an iron core, preferably one made up of iron wires or sheets, is placed in the center of the coil as indicated in Fig. 50, the effect will be found to be readily noticeable. The spark formed will be considerably larger or the shock will be more readily detected.

Let us now consider another arrangement such as shown in Fig. 51. If two or three layers of magnet wire about No. 18 or 19 be wound on an iron core, or one made up of iron wires, and another coil of covered wire of a very large number of turns of fine wire be wound over this wire or in a coil that can be slipped over the first, it will be found that a spark, or shock, can be produced as indicated in the sketch. This is

produced regardless of the fact that there is no electrical connection between the outer and inner coils.

The producing of a voltage in the manner indicated in these cases is commonly known as producing it by induction and in the case where the single coil is used the increase in voltage is said to be brought about by self-induction.

85. Self-Induction.—Let us now consider the probable cause of the effect of the coil in the circuit in Fig. 49 and 50. We have found that by simply inserting a coil of a large number of turns of covered wire the low voltage of the dry cell has been increased many times at the instant the circuit is broken, and that the insert-

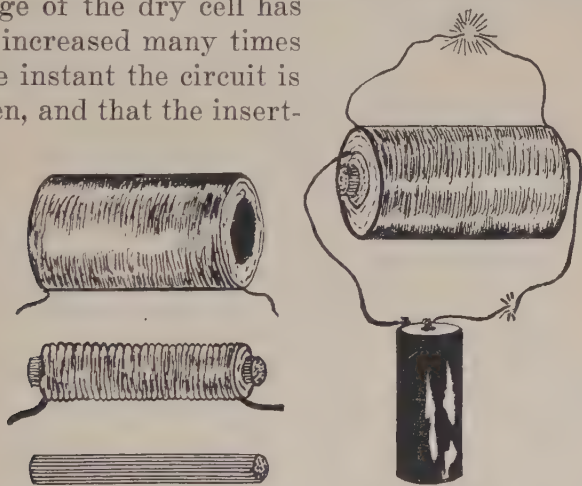


FIG. 51. Illustrating a method of greatly increasing voltage.

ing of the iron core has brought about a more pronounced effect. The facts, that magnetic lines of force always encircle wires when an electrical current flows thru them and that iron provides a good path for lines

of force, show almost conclusively that the lines of force have been the cause of the increased voltage. Also the fact that a voltage is set up in a coil when the lines of force are cut by it (Fig. 45), would tend to prove that the lines of force formed when a current is passing thru the coil, are broken up by the coil when the circuit is opened or the current is shut off, and cause a voltage to be set up in it. This voltage would naturally depend upon the number of turns of wire in the coil and the number of lines of force. In Fig. 49 the effect of increasing the number of lines of force is shown. The increased effect brought about by increasing the number of turns of wire can readily be shown by using two coils connected in such a way that the current flows thru both in the same direction. (If the coils are of equal size and one is placed the reverse of the other, there will be practically no effect.)

86. The Induction Coil.—In our previous discussions it has been pointed out that the voltage of a storage battery or low-voltage generator is much too low to cause a spark to jump across the air space between the terminals of a spark plug. It has been mentioned also that a coil may be used to increase the voltage. It will be seen that this coil may be a suitable application of the effect indicated in Fig. 51. In fact, the complete coil in this figure is what is commonly known as an induction coil. Let us consider this arrangement.

The iron core with the winding of comparatively heavy wire is nothing more or less than an electromagnet. This we know becomes magnetized when an electrical current is passed thru the winding. In other

words, lines of force are formed. When the current is turned on, the lines of force build up; when it is shut off, they disappear. As the circuit is broken, a spark will be formed at the break but it will be rather small if there is a winding of a comparatively small number of turns. Now, if over this electro-magnet we place a coil of a very large number of turns of wire, the lines of force will pass thru this coil also. The changing of the lines of force, by opening the circuit, will cause a voltage to be set up in the outer coil which will depend upon the ratio of the number of turns on the second coil to that on the first. That is, if there are 100 times as many turns on the second coil as are on the first, the voltage at the ends of the second coil will be about 100 times that of the cell, or other source, at the instant that the circuit is opened. Thus the voltage of a battery, or other source of current, can be increased many times by the use of a coil.

In practice, coils are usually placed in suitable containers such as small boxes and may not be readily recognized as anything similar to the sketch shown in Fig. 51. Investigation will usually prove that some combination of this nature is used regardless of its outward appearance.

The inside coil, or the one connected to the source, is called the primary; and the outside coil, or the one that gives the high voltage, is called the secondary coil. The secondary coil gives a high-tension, or high-voltage current. That is, one impressed by a high pressure. Fig. 52 is a typical sketch taken from an automobile reference book. It should be readily understood. The resistance unit is simply a protective de-

vice in the primary circuit. One of the primary and one of the secondary wires are connected together. This will be readily understood as being possible if one takes into consideration the fact that a single wire, or the frame of the automobile may provide a path for several different currents.

87. The Circuit Breaker or Interrupter, and Vibrator.—The high voltage is set up in a secondary winding

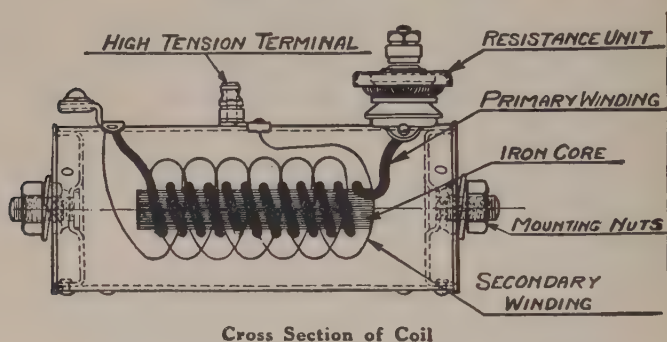


FIG. 52. A typical diagram of an induction coil.

only when there is a decided change in the lines of force. If the circuit is left closed and the current flows continuously there is no effect on the secondary. In the case of an arrangement such as shown in Fig. 51 no spark will be formed, and no shock noticed, unless the circuit is closed and opened. If the wire leading from the cell to the point at which the spark is shown is connected to a file and the primary wire drawn over it, a series of shocks will be noticed, or a series of sparks will be formed. If any other means is provided for causing continuous opening and closing of the circuit, a continuous spark, or series of sparks, will be produced. It is

evident, therefore, that it is necessary to provide some means of opening the circuit at the instant the spark is desired, or some means of causing a continuous opening and closing if a series of sparks is to be produced.

Some coils such as the Delco shown in Fig. 52 are used in connection with a breaker, or timer, shown in Fig. 53. This is indicated also in Fig. 31 of Chap-

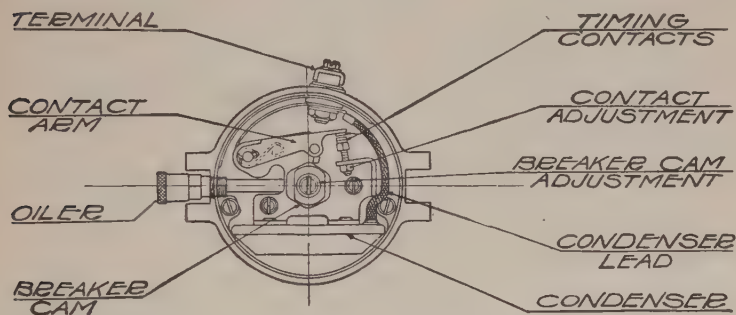


FIG. 53. A diagram of a circuit breaker, or timer.

ter V. In systems of this kind, the primary circuit is opened by a cam which pushes the timing contacts apart at the instant the spark is desired. The timing contacts are in reality the points in the primary circuit where the small spark is shown in Fig. 51. Coils of this kind are called non-vibrating. They give a single spark just at the instant that the points are brought apart.

Other coils are arranged to give a series of sparks when the primary circuit is closed, an example of which is the Ford coil. They make a buzzing sound. A sketch of such a coil and its circuit diagram are shown in Fig. 54. Coils of this kind are equipped with

a vibrator, which operates in a manner similar to the hammer of an electric bell. The vibrator is made of iron and placed near the end of the core, which is an electro-magnet when current flows thru its winding. On the back of the vibrator is placed a metallic point which

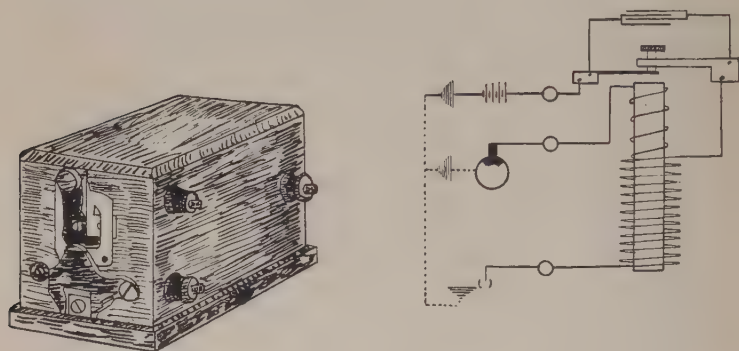


FIG. 54. A sketch and diagram of a spark coil.

just comes in contact with an adjustable screw. The screw and vibrator are connected in the primary circuit. When the switch or timer is closed a current flows thru the primary winding of the coil, magnetizes the core, and causes an attraction of the vibrator which pulls it away from the screw. This opens the circuit and causes a spark, and at the same time the vibrator springs back and closes the circuit again. This continues as long as the switch, or timer, is closed.

88. Timer or Vibrator Points.—It is evident that at the time a primary circuit is opened a spark will be formed where the opening takes place. (See Fig. 51.) This spark is caused by the induction due to the opening of the primary circuit in which there is a coil of

wire and is produced at the timer or vibrator points. These points must, therefore, be of a material which will readily conduct electricity but at the same time withstand the burning effect of the spark. They are made of platinum, tungsten, or sometimes coin silver. These points must also be sufficiently large and in good contact to provide an easy path for the electrical current which must pass thru them. If these requirements are not fulfilled, trouble will be encountered. The points will be burned and pitted and will require repairing or replacing.

89. The Condenser.—A condenser has been indicated on some of the diagrams and it has been mentioned in previous discussions. Now we are in a position to discuss its use. A condenser is a device made up of alternate layers of conducting material, such as tin foil, and a suitable insulating material. Half of the conductors are connected at one end and the other half at the other ends. To these groups connections are made. Such a device when connected across the breaker, or timer, or vibrator points, that is in parallel with them, has the faculty of taking up the electricity which would go to making a spark between these terminals, or points. Thus the condenser reduces the spark at the points, reducing the burning, and assists in making the primary current stronger and consequently better for producing the ignition spark across the terminals of the spark plug in the secondary. Failure of the condenser may cause burning and pitting of the points or a noticeable weakness of the spark at the plugs. It will not function properly if the insulation breaks down.

90. High-Tension Magnetos.—The simple magneto previously described, which depends upon the cutting of lines of force, or the changing of lines of force, gives a comparatively low voltage. Such magnetos provide a voltage which is suitable for ignition only when they are used in connection with induction, or

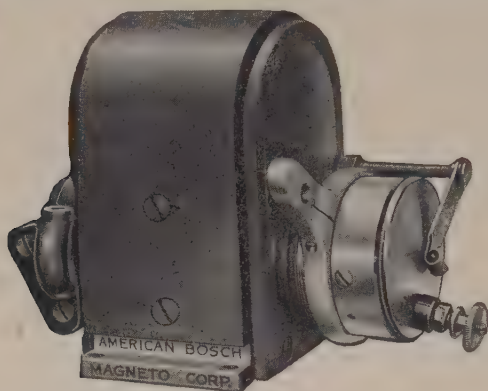


FIG. 55. A high-tension magneto (Bosch).

spark, coils. The voltage of such a magneto depends upon the number of turns of wire and the speed at which they are cut by lines of force. These cannot logically be sufficient to cause an extremely high voltage.

It is possible, however, to make arrangements within the magneto itself to have two windings, a primary and a secondary, and have somewhat of a combination of magneto and induction coil effect. The voltage of the primary can be made to induce a high voltage in the secondary which can be used directly for ignition purposes. Magnetos of this type are commonly known as high-tension magnetos.

In Fig. 55 is shown a high-tension magneto and in Fig. 56 the circuit diagram for a single-cylinder engine. This magneto produces its own high voltage directly in the magneto armature (rotating part of the magneto)

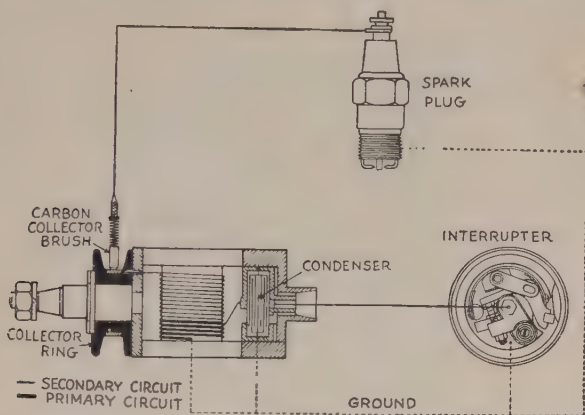


FIG. 56. The magneto-circuit diagram for a single cylinder engine.

without the aid of a separate step-up coil, and it has the timer as a part of the magneto itself.

The armature winding is composed of two sizes of wire, one size comparatively large and the other very fine. The large wire constitutes the primary, or low tension circuit, and the very fine wire the secondary or high tension circuit.

The rotation of the armature between the poles of the strong permanent magnets sets up or induces a current in the primary circuit, and the voltage is stepped up by the quick opening of the primary circuit by means of the interrupter, or breaker. At the opening of the primary circuit a high voltage is induced in

the secondary circuit. Thru the slip-ring on the armature and the brush a high-tension current is carried to the spark plug and then back to the other end of the secondary thru the frame of the engine and the magneto.

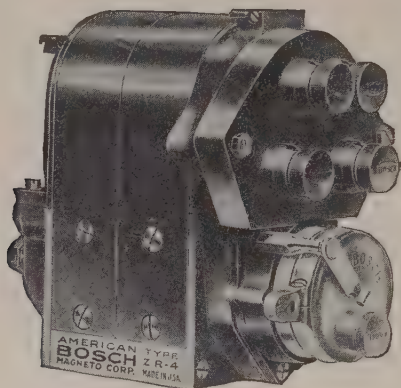


FIG. 57. A high-tension magneto for a four-cylinder engine (Bosch).

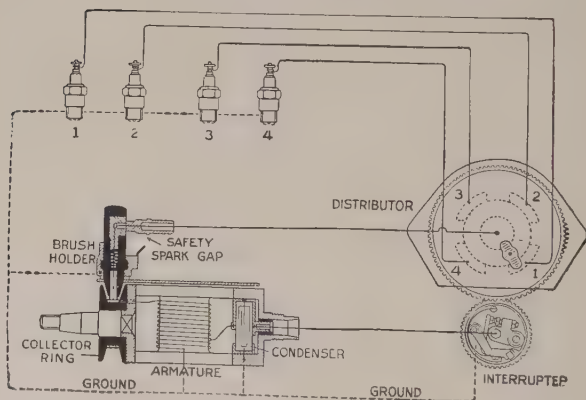


FIG. 58. Circuit diagram for the magneto on a four-cylinder engine.

Figs. 57 and 58 show a similar magneto for a four-cylinder engine and the connection diagram.

QUESTIONS ON CHAPTER VII

1. What are magnetos?
2. What are generators?
3. What are the three fundamental essentials in all magnetos?
4. Describe a method whereby electrical pressure can be caused by means of a coil of wire and a magnet.
5. Upon what does the direction of the current depend?
6. Explain what this indicates?
7. What shows that lines of force must be involved?
8. How does this show that cutting lines of force by a conductor causes voltage?
9. What four important conclusions can be drawn from the experimenting with the magnet and the coil of wire?
10. Show how the Ford magneto is an application of the cutting of conducting material with lines of force.
11. How does the armature type of magneto bring about the cutting of lines of force by a coil of wire?
12. What kind of current is delivered by magnetos?
13. Can the current be used for charging storage batteries?
14. What are the principal parts of a generator?
15. What is the function of the commutator on the generator armature shaft?
16. Explain how a coil of wire may be used to cause an increase in voltage.
17. What effect has an iron core upon this increase?
18. Upon what does the inductive effect depend?
19. What is an induction coil?
20. Of what does the induction coil consist?
21. What is the primary?
22. What is the secondary?
23. Why is it necessary to have a circuit breaker, or interrupter, or vibrator?
24. What is meant by a vibrating coil?
25. What is meant by a non-vibrating coil?

26. Make a diagram showing how a coil is connected in a circuit.
27. What may happen to the timer or vibrator points if they are not of suitable material?
28. What is the purpose of the condenser?
29. What is a condenser?
30. What is a high-tension magneto?
31. How does it differ from a low-tension magneto?
32. Make a diagram showing the wiring for a high-tension magneto.

CHAPTER VIII

ELECTRICAL TROUBLES AND REMEDIES

91. Possible Troubles.—The complete electrical system in an automobile consists of a number of circuits of various kinds and involves lighting equipment, ignition equipment, motor equipment and generator equipment in addition to the storage battery. It is evident that under the usage to which the average automobile is subjected there is always a possibility that troubles may arise due to the vibration or jar, from wear, or from improper use.

These possible troubles may be divided into five general classes as follows:

1. Troubles which are common to all circuits.
2. Lighting troubles.
3. Ignition troubles.
4. Motor and generator troubles.
5. Storage battery troubles.

92. Possible Troubles Common to all Circuits.—It is said that about fifty per cent of all electrical troubles are due to faulty contacts or loose connections in wiring. The vibration of the car will loosen the connections eventually and this brings about poor contact which results in trouble. It is possible also that wires may be accidentally broken and that insulation or insulating coverings may be worn to such an extent as to cause open or short circuits. It is evident, therefore, that the possible troubles in any circuit may be due to the following:

1. Faulty contacts or poor connections.
2. Open circuits.
3. Short circuits.

93. Faulty Contacts or Poor Connections.—Since every electrical device depends for its operation upon the flow of electricity thru it, and since electricity will flow only thru a suitably provided circuit, which must be of conducting materials, it is obvious that loose or dirty contacts or poor connections may readily cause trouble. Oil, dirt, or grease on terminals may cause a holding up of the electrical current and thus the failure of an electrical device to function properly.

In cases where faulty contacts or poor connections have taken effect, the device may operate but not satisfactorily. The starting motor may turn slowly and lack power, the lamps may be dim or fail to light at all, the horn may give only a feeble sound, or similar troubles may be noted.

It is well to consider the possibility of faulty contacts and poor connections first of all when attempting to locate the cause of trouble. If connection terminals are found loose or dirty, or if switches or other contact parts are found dirty, covered with oil, or corroded, careful cleaning and tightening of the connections may remove the cause of trouble. The contact parts may be cleaned with ammonia, with sand paper, or scraped with a knife in some cases.

94. Open Circuits.—Any break or opening in a circuit causes what is commonly known as an open circuit. This is simply a break in the continuous path which, obviously, shuts off the current and the device to which the path leads fails to operate.

An open circuit may be caused by a loose connection or by an actual break in the wire. Sometimes the break or loose connection causes only an intermittent failure of the device. That is, the lights may flicker, the horn may operate sometimes but fail at others, or the ignition may fail and then suddenly function again. This is possible because of the fact that the loose or broken connections may be brought into contact or apart by the vibration or jar of the automobile.

If an open circuit is suspected, look for loose or disconnected terminals. Where the wires are subject to vibration or bending, look for breaks. If the wire in which the break is suspected is concealed, it is possible to test it by connecting a battery at one end and a test lamp, bell, or other device at the other end. If the testing device operates, there is no break. The frame of the car may be used as one side of a circuit if it is desired to test a single wire.

95. Short Circuits.—When accidental connection is made between two parts of a circuit which provides a short path for the electricity, it is said that a short circuit exists. Such a defect not only causes a failure of a device to which the wires lead but also a wasteful use of electricity which will in many cases cause an excessive load, the blowing of fuses, or the burning of the covering on the wires and perhaps the burning of the wires themselves.

If the ammeter reading is extremely high, if the storage battery runs down, even tho not used to any great extent, or if fuses are blown or wires get hot, a short circuit is probably the cause of the trouble.

Short circuits are caused most frequently by the

wearing off of the insulating covering or by the breaking down of insulating materials. Bare spots on wires should be covered with friction tape and broken pieces of insulating material should be replaced. If the covering on the wires is worn excessively it is well to replace them with new ones of the right kind and size.

In a one-wire system a short circuit will be formed if the covering is worn thru on a wire and it comes in contact with the frame. In a two-wire system the wires must touch each other or both come in contact with some conducting material.

If the ammeter reads when everything is turned off or if other symptoms of a short circuit are evident, a test can be made by opening all switches, disconnecting one of the wires to the battery, and connecting in the circuit at the battery a test lamp or some other indicating device. A file can be used in place of the lamp. If connections are made in this way, or one of the wires drawn over the file, evidence of electrical current indicates a short circuit.

96. Lighting Troubles.—Among the common troubles arising in connection with lighting are the following:

1. The lamps become dirty and need cleaning and adjusting.
2. Lamp bulbs burn out or become broken.
3. The light wiring terminals need repairing.
4. The lighting switch becomes dirty or defective.
5. The wiring becomes worn to such an extent that rewiring is advisable.

97. Cleaning and Adjusting Lamps.—Cleaning and adjusting lamps requires the opening of the lamps,

the cleaning of the glass with a piece of waste or suitable cloth, and the replacing of the cover. When adjusting lamps the desires of the owner and the lighting regulations for various communities should be taken

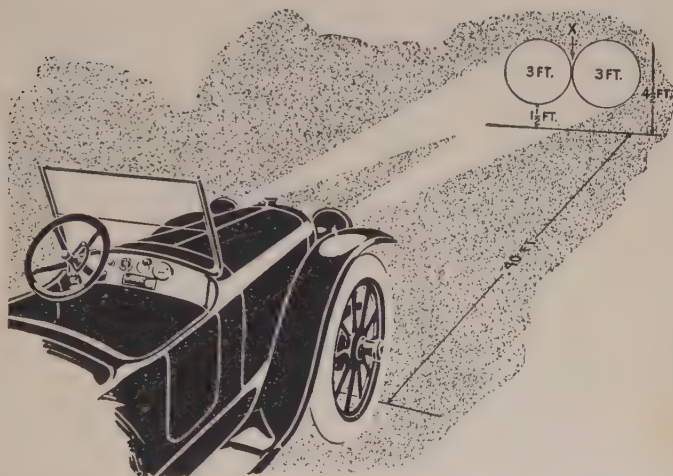


FIG. 59. One method of checking up on lamp adjustment.

into consideration. Fig. 59 shows one method of checking up on the lamp adjustment.

98. Installing New Lamp Bulbs.—If a lamp fails to light and no trouble can be detected in the connections to it, it is possible that the bulb has been burned out and must be replaced. When this is done the following should be the order of operations: (1) remove the cover, (2) remove the bulb, (3) inspect the bulb, (4) replace with a new bulb of suitable size and voltage, if necessary, (5) try out the new bulb and (6) replace the cover. Remember that some bulbs are single con-

tact and some are double contact. Look at the bottom to see which it is before getting a new bulb.

99. Other Repair Work on the Lighting System.—If light wiring terminals are found to need repairing, it may be desirable to clean and solder them or to tighten the connections firmly.

If troubles arise in the lighting circuits and the bulbs have been inspected and found in good condition it is possible that the lighting switch needs cleaning or repairing. The two most common troubles are dirty or corroded connections and trouble due to dirty or bent blades. These can be remedied by scraping the connections or washing the parts with ammonia water, or in the case of the latter, by bending the blades until they make good contact.

In locating trouble if it is not apparent, a test lamp can be used in connection with the battery on the car or with a separate battery. First test the battery to the ammeter, then from the ammeter to the main connection on the switch. If these lines are found to be good and the lights still fail to operate the trouble must be in the switch and can be quite readily located.

100. Ignition Troubles.—Among the most common troubles arising in connection with ignition are the following:

1. Spark plugs become dirty or broken.
2. Ignition switch becomes dirty or corroded.
3. The breaker points become dirty or corroded.
4. The distributor becomes dirty or worn.
5. The condenser becomes shorted or disconnected.
6. The coil fails to function.
7. The magneto fails to function.

101. Cleaning and Adjusting Spark Plugs.—Since the spark plug terminals are inside the cylinder where the gas is exploded and lubricating oil is often burned in considerable quantities, it is not uncommon for the spark plugs to become covered with carbon. Then, too, it is possible that the gap between the sparking points of the plugs may need adjusting.

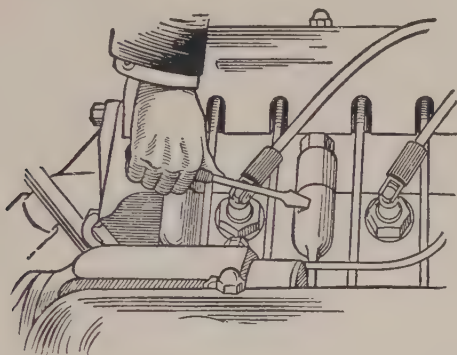


FIG. 60. Short-circuiting a spark plug with a screwdriver. (Touch the motor frame first.)

If one or more cylinders seem to be “missing” it is possible to locate those in which ignition is failing in the following manner: While the motor is running place a screwdriver or other metal piece in contact with the frame of the engine and bring it down in contact with the terminal of the first spark plug. If a difference in the operation of the motor is noticed, the cylinder tested is functioning. The manner in which this test may be made is illustrated in Fig. 60. If no difference is detected, the cylinder is probably the one in which ignition is failing. Each cylinder can be tested

in this manner. When this is done, the metal in the screwdriver makes a direct connection between the wire leading to the spark plug and the return thru the frame and thus makes a direct path or short circuit and no spark is produced in the cylinder. The voltage at the spark plug is sufficiently high to give a good but harmless shock if this operation is not done properly. *Always touch the frame of the motor first and then the spark plug terminal.*

If a defective spark plug is suspected it should be cleaned and adjusted.

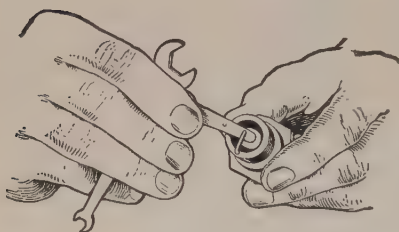


FIG. 61. Adjusting the gap in a spark plug.

This should be done in the following manner:

(1) Disconnect the high-tension wire leading to the plug, (2) remove the plug with a suitable wrench, (3) remove the carbon with a rag saturated with gasoline. (If any oil remains on the plug use a wire brush, muriatic acid, or alcohol but do not scrape the porcelain with a knife because this scrapes off the glaze) (4) examine carefully the porcelain for cracks and breaks, (5) examine the gasket and replace with a new one if necessary, (6) adjust the points to the proper gap (roughly the thickness of a dime, or with a gage as illustrated in Fig. 61) and (7) re-insert the plug and connect the high-tension wire.

If the gap is too wide the motor may miss on a heavy pull at slow speed, and too narrow a gap may cause the motor to miss when running fast.

In a Ford the ignition can be tested by pressing down on the vibrator of the coil on the dash. This stops the spark to the cylinder by keeping the coil circuit open and the functioning of any particular cylinder can be noted. This does away with the necessity of short-circuiting the plugs.

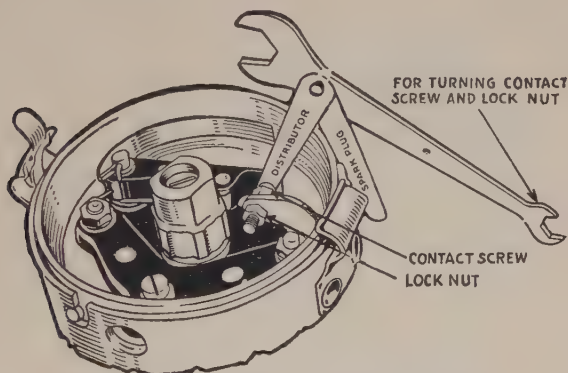


Fig. 62. Adjusting breaker contacts.

102. Cleaning and Adjusting Breaker Points.—

Breaker points are points which open and close suitably for causing the spark at the proper time. These are subjected to certain sparking which may cause corrosion or burning. Then, too, the points may need adjusting or repairing.

Pitting or corroding may be brought about by poor contact or by a defective condenser.

If defective ignition tends to show that the breaker points are defective the points should be cleaned and perhaps smoothed on an oil stone or very fine emery cloth and adjusted to meet squarely, or perhaps replaced with new ones. The adjustment must be such

that the gap will meet individual requirements, the space varying from $1/64$ to $1/32$ inch. Sometimes a suitable gage is available which can be used as illustrated in Fig. 62.

103. Remedying Other Ignition Troubles.—If the sparks in the cylinders are not entirely satisfactory and the plugs and connections are found to be good,

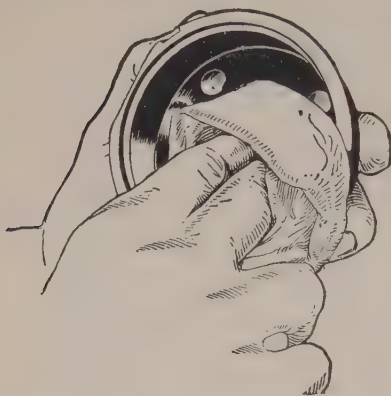


FIG. 63. Cleaning a distributor head.

continued burning of the breaker points may be caused by a defective condenser. If this is thought to be the trouble a new condenser can be connected.

Other remedies which may be necessary in the ignition may include cleaning the distributor. If dirt, oil or moisture is allowed to collect on the distributor head the ignition may be defective. Therefore, the distributor head and rotor must be kept clean. This can be accomplished by means of a cloth saturated with ammonia as illustrated in Fig. 63.

If the coil or magneto fails to function, careful inspection will usually show some minor defect which can be detected and remedied quite readily by one familiar with their principles.

104. Motor and Generator Troubles.—The motor and generator consisting, as they do, principally of a field, an armature with a commutator on its shaft, and

brushes cause very little trouble ordinarily if the connections are good and the conducting parts are kept clean and smooth. The connections should be inspected first in case of trouble.

Other things which may occur and cause trouble are the following:

1. The voltage of the generator may not be satisfactory and may have to be regulated.
2. The commutator may be dirty or worn and need cleaning or turning down.
3. The brushes may be worn excessively or not fit, and need adjusting or replacing.

105. Regulating Voltage.—In automobile work the voltage of the generator may be regulated in any of several ways. The relative voltage shows up, of course, on the ammeter reading. That is, if the meter reads high the voltage is high. In every case the speed of the armature and the strength of the field govern the output. This being the case, it is evident that any reduction of the speed of the armature or weakening of the field will cause a decrease in the voltage and vice versa.

In many cases a three-brush generator is used. This third brush is usually adjustable. The one end of the field winding is connected to this brush and the strength of the field can be regulated by changing the position of the brush.

106. Cleaning or Repairing the Motor or Generator.
—The commutator on the generator or motor may become covered with a film of oil or dirt and not function properly. This may cause the machine to fail to operate. The commutator must carry the current from the

brushes to the armature coils and therefore must be in good contact with them as well as clean and smooth. The bars of the commutator are of copper and are insulated from each other by pieces of mica. It is possible that the commutator will wear down so that these pieces of mica will protrude and interfere with the smooth operation of the machine. In such a case they must be cut down. Thus we see that among the repairs somewhat common to this particular part of the electrical system may be the following:

1. Cleaning the commutator and brushes.
2. Replacing brushes.
3. Turning down the commutator.
4. Undercutting the mica.

107. Cleaning the Commutator and Brushes.—If the machine does not function properly and it is suspected that the commutator and brushes need cleaning, remove the cover plate, clean the brushes and commutator with fine sandpaper, and fit the brushes to the commutator. Emery cloth should never be used for this purpose because emery is a conductor and small particles might short-circuit the commutator bars. The commutator can be cleaned while the machine is in motion.

Obviously the brushes should fit the commutator as perfectly as possible and the greater the area of contact the better. The brushes can be made to fit by stopping the machine, inserting a piece of sandpaper somewhat wider than the brushes so its rough side is in contact with them, and moving it back and forth. When this is done the sandpaper strip should be pulled around the commutator so at least one-half of the commutator is

covered to avoid sanding off the edges of the brushes where they should be in close contact with the commutator. If this is done in the proper manner the curvature of the brushes and that of the commutator will be such as to insure a perfect fit.

The springs on the brushes should be such that the latter are held in good contact with the commutator at all times but excessive pressure will cause undue wear.

If the brushes are badly worn it may be well to replace them with new ones.

108. Turning Down the Commutator.—If the commutator of a motor or generator is found to be worn unevenly or to contain grooves which cannot be removed with sandpaper, it may be necessary to put the armature in a lathe and turn the commutator down. If this is done, a fine cut should be taken and the tool should not be crowded to an extent which will cause a rough surface.

109. Undercutting Mica.—The mica may need undercutting. This should always be done when the commutator has been turned down. The undercutting may be accomplished by placing the armature in a lathe and using a thin, square-pointed tool ground to the exact size of the strips of mica and placed in the tool holder.

Another method of doing this when a lathe is not available is by the use of a hack-saw blade ground to the proper thickness.

110. Other Troubles.—Other troubles may arise which will require repair work. If this is found to be the case, always remember the fundamental require-

ments for all electrical circuits and the principles upon which the various devices operate. If these are always kept in mind and one applies them whenever possible, he should be able to do many jobs in connection with the use and upkeep of an automobile, and with this knowledge as a foundation should be able to progress rapidly in the various occupations involving automotive electrical work.

QUESTIONS ON CHAPTER VIII

1. What five general types of troubles may arise in an automobile?
2. Explain what troubles are likely to happen in any electrical circuit.
3. How is it possible that faulty contacts or poor connections may cause trouble?
4. Explain what is meant by an open circuit.
5. Explain what is meant by a short circuit.
6. Explain how an open circuit may be detected and located.
7. What may cause a short circuit?
8. What may happen if a short circuit is formed?
9. How can a short circuit be located?
10. What five troubles may arise in connection with lighting?
11. Explain how to clean and adjust lamps.
12. How is it possible to install a new lamp bulb?
13. What may cause trouble in a lighting switch?
14. Explain how to test to see whether or not trouble exists in the lighting switch.
15. List seven troubles which may arise in connection with the ignition.
16. What troubles may arise in the spark plugs?
17. How is it possible to locate a defective spark plug?
18. Why should the frame of the motor be touched first when short-circuiting a spark plug?
19. Explain how this test makes it possible to detect a defective plug.

20. How can defective plugs be detected on a Ford?
21. How should a spark plug be cleaned?
22. What may happen if the spark-plug gap is too wide? If too narrow?
23. What trouble may arise at the breaker points?
24. How is it possible to smooth the breaker points?
25. What other ignition troubles may arise?
26. How is it possible to clean the distributor head and rotor?
27. What work may be involved in taking care of a motor or generator?
28. What are the two fundamental things which affect the voltage of a generator?
29. How can the voltage be changed if a three-brush generator is used?
30. What simple repair jobs may arise in connection with the motor or generator?
31. Explain how to clean the commutator and brushes.
32. Why should the use of emery cloth be avoided?
33. Why should the sandpaper or sand cloth strip be wider than the brushes?
34. Why should it be pulled around the commutator so as to be in contact with at least one-half of it?
35. When may it be necessary to turn down the commutator?
36. How should this be done?
37. How is it possible to cut down the micas between the commutator segments?

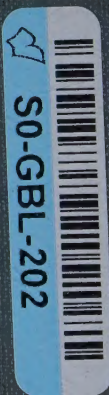
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